



An Object Oriented Finite Element Library

Reference Guide

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Chapter 1

Module Index

1.1 Modules

Here is a list of all modules:

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Chapter 2

Namespace Index

Chapter 3

Hierarchical Index

3.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

AbsEqua< complex.t >	123
Equation< complex.t, NEN_, NEE_, NSN_, NSE_ >	484
AbsEqua< double >	123
Equation< double, NEN_, NEE_, NSN_, NSE_ >	484
AbsEqua< real.t >	123
Equation< real.t, NEN_, NEE_, NSN_, NSE_ >	484
LocalMatrix< complex.t, NEE_, NEE_ >	671
LocalMatrix< complex.t, NSE_, NSE_ >	671
LocalMatrix< double, NEE_, NEE_ >	671
LocalMatrix< double, NSE_, NSE_ >	671
LocalMatrix< real.t, NEE_, NEE_ >	671
LocalMatrix< real.t, NSE_, NSE_ >	671
LocalMatrix< T_, NEE_, NEE_ >	671
LocalMatrix< T_, NSE_, NSE_ >	671
LocalVect< complex.t, NEE_ >	677
LocalVect< complex.t, NSE_ >	677
LocalVect< double, NEE_ >	677
LocalVect< double, NSE_ >	677
LocalVect< real.t, NEE_ >	677
LocalVect< real.t, NSE_ >	677
LocalVect< T_, NEE_ >	677
LocalVect< T_, NSE_ >	677
AbsEqua< T_ >	123
Equation< T_, NEN_, NEE_, NSN_, NSE_ >	484
Equa_Electromagnetics< complex.t, 3, 3, 2, 2 >	414
EC2D1T3	311
HelmholtzBT3	520
Equa_Electromagnetics< real.t, 3, 6, 2, 4 >	414
Equa_Fluid< real.t, 3, 6, 2, 4 >	427
TINS2DT3B	895
Equa_Fluid< real.t, 4, 8, 2, 4 >	427
NSP2DQ41	737
Equa_Laplace< real.t, 2, 2, 1, 1 >	440
Laplace1DL2	572

Equa.Laplace< real.t, 3, 3, 1, 1 >	440
Laplace1DL3	587
Equa.Laplace< real.t, 3, 3, 2, 2 >	440
Laplace2DFVT	602
Laplace2DMHRT0	615
Laplace2DT3	629
Equa.Solid< double, 8, 24, 4, 12 >	453
Elas3DH8	371
Equa.Solid< real.t, 2, 12, 1, 1 >	453
Beam3DL2	142
Equa.Solid< real.t, 2, 4, 1, 2 >	453
Bar2DL2	125
Equa.Solid< real.t, 3, 6, 2, 4 >	453
Elas2DT3	352
Equa.Solid< real.t, 4, 12, 3, 9 >	453
Elas3DT4	387
Equa.Solid< real.t, 4, 8, 2, 4 >	453
Elas2DQ4	335
Equa.Therm< real.t, 2, 2, 1, 1 >	468
DC1DL2	176
Equa.Therm< real.t, 3, 3, 2, 2 >	468
DC2DT3	196
DC3DAT3	239
Equa.Therm< real.t, 4, 4, 3, 3 >	468
DC3DT4	259
Equa.Therm< real.t, 6, 6, 3, 3 >	468
DC2DT6	219
Equa.Electromagnetics< T_, NEN_, NEE_, NSN_, NSE_ >	414
Equa.Fluid< T_, NEN_, NEE_, NSN_, NSE_ >	427
Equa.Laplace< T_, NEN_, NEE_, NSN_, NSE_ >	440
Equa.Solid< T_, NEN_, NEE_, NSN_, NSE_ >	453
Equa.Therm< T_, NEN_, NEE_, NSN_, NSE_ >	468
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Circle	174
Ellipse	412
Polygon	813
Rectangle	825
Sphere	863
Triangle	??
FMM2D	505
FMM3D	506
FMMSolver	508
Funct	509
Gauss	511
Grid	511
IOField	557
IPF	560
Iter< T_ >	571
LocalMatrix< T_, NR_, NC_ >	671
LocalVect< T_, N_ >	677
Material	682
Matrix< T_ >	684
BMatrix< T_ >	163
DMatrix< T_ >	280
DSMatrix< T_ >	301
SkMatrix< T_ >	834
SkSMatrix< T_ >	849
SpMatrix< T_ >	865
TrMatrix< T_ >	921
Mesh	692
MeshAdapt	713
Muscl	717
Muscl1D	721
ICPG1D	536
LCL1D	645
Muscl2DT	724
ICPG2DT	544
LCL2DT	651
Muscl3DT	728
ICPG3DT	551
LCL3DT	657
Node	732
NodeList	736
ODESolver	752
Partition	760
PETScMatrix< T_ >	767
PETScVect< T_ >	777
PETScWrapper< T_ >	799
PhaseChange	806
Point< T_ >	807
Point2D< T_ >	810
Prec< T_ >	816
Prescription	820

Reconstruction	824
Side	827
SideList	833
SteklovPoincare2DBE	882
Tabulation	884
Timer	889
TimeStepping	890
UserData< T_ >	931
Vect< T_ >	934
Point< real_t >	807
UserData< double >	931
Vect< real_t >	934

Chapter 4

Class Index

4.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

AbsEqua< T_ >	Mother abstract class to describe equation	123
Bar2DL2	To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node	125
Beam3DL2	To build element equations for 3-D beam equations using 2-node lines	142
BiotSavart	Class to compute the magnetic induction from the current density using the Biot-Savart formula	157
BMatrix< T_ >	To handle band matrices	163
Brick	To store and treat a brick (parallelepiped) figure	172
Circle	To store and treat a circular figure	174
DC1DL2	Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements	176
DC2DT3	Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles	196
DC2DT6	Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles	219
DC3DAT3	Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles	239
DC3DT4	Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra	259
DMatrix< T_ >	To handle dense matrices	280
Domain	To store and treat finite element geometric information	297

DSMatrix< T_ >	To handle symmetric dense matrices	301
EC2D1T3	Eddy current problems in 2-D domains using solenoidal approximation	311
Edge	To describe an edge	326
EdgeList	Class to construct a list of edges having some common properties	328
EigenProblemSolver	Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, <i>i.e.</i> Find scalars λ and non-null vectors v such that $[K]\{v\} = \lambda[M]\{v\}$ where $[K]$ and $[M]$ are symmetric matrices. The eigenproblem can be originated from a PDE. For this, we will refer to the matrices K and M as <i>Stiffness</i> and <i>Mass</i> matrices respectively	329
Elas2DQ4	To build element equations for 2-D linearized elasticity using 4-node quadrilaterals	335
Elas2DT3	To build element equations for 2-D linearized elasticity using 3-node triangles	352
Elas3DH8	To build element equations for 3-D linearized elasticity using 8-node hexahedra	371
Elas3DT4	To build element equations for 3-D linearized elasticity using 4-node tetrahedra	387
Element	To store and treat finite element geometric information	402
ElementList	Class to construct a list of elements having some common properties	411
Ellipse	To store and treat an ellipsoidal figure	412
Equa_Electromagnetics< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for Electromagnetics Equation classes	414
Equa_Fluid< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for Fluid Dynamics Equation classes	427
Equa_Laplace< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for classes about the Laplace equation	440
Equa_Solid< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for Solid Mechanics Finite Element classes	453
Equa_Therm< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for Heat transfer Finite Element classes	468
Equation< T_, NEN_, NEE_, NSN_, NSE_ >	Abstract class for all equation classes	484
Estimator	To calculate an a posteriori estimator of the solution	499
FastMarching2D	To run a Fast Marching Method on 2-D structured uniform grids	499
FEShape	Parent class from which inherit all finite element shape classes	500
Figure	To store and treat a figure (or shape) information	504
FMM2D	Class for the fast marching 2-D algorithm	505
FMM3D	Class for the 3-D fast marching algorithm	506

FMMSolver	The Fast Marching Method solver	508
Funct	A simple class to parse real valued functions	509
Gauss	Calculate data for Gauss integration	511
Grid	To manipulate structured grids	511
HelmholtzBT3	Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles	520
Hexa8	Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation	534
ICPG1D	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D	536
ICPG2DT	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D	544
ICPG3DT	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D	551
IOField	Enables working with files in the XML Format	557
IPF	To read project parameters from a file in IPF format	560
Iter< T_>	Class to drive an iterative process	571
Laplace1DL2	To build element equation for a 1-D elliptic equation using the 2-Node line element (P_1)	572
Laplace1DL3	To build element equation for the 1-D elliptic equation using the 3-Node line (P_2)	587
Laplace2DFVT	To build and solve the Laplace equation using a standard Finite Volume method	602
Laplace2DMHRT0	To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas RT_0)	615
Laplace2DT3	To build element equation for the Laplace equation using the 2-D triangle element (P_1)	629
LCL1D	Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme	645
LCL2DT	Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles	651
LCL3DT	Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra	657
Line2	To describe a 2-Node planar line finite element	664

Line2H	To describe a 2-Node Hermite planar line finite element	667
Line3	To describe a 3-Node quadratic planar line finite element	669
LocalMatrix< T_l, NR_l, NC_l >	Handles small size matrices like element matrices, with a priori known size . .	671
LocalVect< T_l, N_l >	Handles small size vectors like element vectors	677
Material	To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members	682
Matrix< T_l >	Virtual class to handle matrices for all storage formats	684
Mesh	To store and manipulate finite element meshes	692
MeshAdapt	To adapt mesh in function of given solution	713
Muscl	Parent class for hyperbolic solvers with Muscl scheme	717
Muscl1D	Class for 1-D hyperbolic solvers with Muscl scheme	721
Muscl2DT	Class for 2-D hyperbolic solvers with Muscl scheme	724
Muscl3DT	Class for 3-D hyperbolic solvers with Muscl scheme using tetrahedra	728
Node	To describe a node	732
NodeList	Class to construct a list of nodes having some common properties	736
NSP2DQ41	Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using Q_1/P_0 element and a penalty formulation for the incompressibility condition	737
ODESolver	To solve a system of ordinary differential equations	752
Partition	To partition a finite element mesh into balanced submeshes	760
Penta6	Defines a 6-node pentahedral finite element using P_1 interpolation in local coordinates (s.x,s.y) and Q_1 isoparametric interpolation in local coordinates (s.x,s.z) and (s.y,s.z)	765
PETScMatrix< T_l >	To handle matrices in sparse storage format using the Petsc library	767
PETScVect< T_l >	To handle general purpose vectors using Petsc	777
PETScWrapper< T_l >	This class is a wrapper to be used when the library Petsc is installed and used with OFELI	799
PhaseChange	This class enables defining phase change laws for a given material	806
Point< T_l >	Defines a point with arbitrary type coordinates	807
Point2D< T_l >	Defines a 2-D point with arbitrary type coordinates	810

Polygon	To store and treat a polygonal figure	813
Prec< T_ >	To set a preconditioner	816
Prescription	To prescribe various types of data by an algebraic expression. Data may consist in boundary conditions, forces, tractions, fluxes, initial condition. All these data types can be defined through an enumerated variable	820
Quad4	Defines a 4-node quadrilateral finite element using Q_1 isoparametric interpolation	822
Reconstruction	To perform various reconstruction operations	824
Rectangle	To store and treat a rectangular figure	825
Side	To store and treat finite element sides (edges in 2-D or faces in 3-D)	827
SideList	Class to construct a list of sides having some common properties	833
SkMatrix< T_ >	To handle square matrices in skyline storage format	834
SkSMatrix< T_ >	To handle symmetric matrices in skyline storage format	849
Sphere	To store and treat a sphere	863
SpMatrix< T_ >	To handle matrices in sparse storage format	865
SteklovPoincare2DBE	Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary element	882
Tabulation	To read and manipulate tabulated functions	884
Tetra4	Defines a three-dimensional 4-node tetrahedral finite element using P_1 interpolation	887
Timer	To handle elapsed time counting	889
TimeStepping	To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$	890
TINS2DT3B	Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles	895
Triang3	Defines a 3-Node (P_1) triangle	910
Triang6S	Defines a 6-Node straight triangular finite element using P_2 interpolation	913
Triangle	To store and treat a triangle	??
triangle	Defines a triangle. The reference element is the rectangle triangle with two unit edges	918
TrMatrix< T_ >	To handle tridiagonal matrices	921

UserData< T_ >	
Abstract class to define by user various problem data	931
Vect< T_ >	
To handle general purpose vectors	934

Chapter 5

Module Documentation

5.1 General Purpose Equations

Gathers equation related classes.

Classes

- class [AbsEqua< T_ >](#)
Mother abstract class to describe equation.
- class [Equation< T_, NEN_, NEE_, NSN_, NSE_ >](#)
Abstract class for all equation classes.
- class [Estimator](#)
To calculate an a posteriori estimator of the solution.

Functions

- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalVect< T_ , N_ > &be, Vect< T_ > &b)`
Assemble local vector into global vector.
- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalMatrix< T_ , N_ , N_ > &ae, Vect< T_ > &b)`
Assemble diagonal local vector into global vector.
- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalMatrix< T_ , N_ , N_ > &ae, Matrix< T_ > *A)`
Assemble local matrix into global matrix.
- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalMatrix< T_ , N_ , N_ > &ae, SkMatrix< T_ > &A)`
Assemble local matrix into global skyline matrix.
- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalMatrix< T_ , N_ , N_ > &ae, SkSMatrix< T_ > &A)`
Assemble local matrix into global symmetric skyline matrix.
- `template<class T_ , size_t N_ , class E_ >`
`void element_assembly (const E_ &e, const LocalMatrix< T_ , N_ , N_ > &ae, SpMatrix< T_ > &A)`

Assemble local matrix into global sparse matrix.

- `template<class T_, size_t N_>`
`void side_assembly (const Element &e, const LocalMatrix< T_, N_, N_ > &ae, SpMatrix< T_ > &A)`

Side assembly of local matrix into global matrix (as instance of class [SpMatrix](#)).

- `template<class T_, size_t N_>`
`void side_assembly (const Element &e, const LocalMatrix< T_, N_, N_ > &ae, SkSMatrix< T_ > &A)`

Side assembly of local matrix into global matrix (as instance of class [SkSMatrix](#)).

- `template<class T_, size_t N_>`
`void side_assembly (const Element &e, const LocalMatrix< T_, N_, N_ > &ae, SkMatrix< T_ > &A)`

Side assembly of local matrix into global matrix (as instance of class [SkMatrix](#)).

- `template<class T_, size_t N_>`
`void side_assembly (const Element &e, const LocalVect< T_, N_ > &be, Vect< T_ > &b)`

Side assembly of local vector into global vector.

- `ostream & operator<< (ostream &s, const Estimator &r)`

Output estimator vector in output stream.

5.1.1 Detailed Description

Gathers equation related classes.

5.1.2 Function Documentation

void element_assembly (const E_ & e, const LocalVect< T_, N_ > & be, Vect< T_ > & b)

Assemble local vector into global vector.

Parameters

in	<i>e</i>	Reference to local entity (Element or Side)
in	<i>be</i>	Local vector
in,out	<i>b</i>	Global vector

void element_assembly (const E_ & e, const LocalMatrix< T_, N_, N_ > & ae, Vect< T_ > & b)

Assemble diagonal local vector into global vector.

Parameters

in	<i>e</i>	Reference to local entity (Element or Side)
in	<i>ae</i>	Local matrix
in,out	<i>b</i>	Global vector

void element_assembly (const E_ & e, const LocalMatrix< T_, N_, N_ > & ae, Matrix< T_ > * A)

Assemble local matrix into global matrix.

This function is to be called with an abstract pointer to matrix (class [Matrix](#))

Parameters

in	e	Reference to local entity (Element or Side)
in	ae	Local matrix
in,out	A	Pointer to global matrix

void element_assembly (const E_ & e , const LocalMatrix< T_, N_, N_ > & ae , SkMatrix< T_ > & A)

Assemble local matrix into global skyline matrix.

Parameters

in	e	Reference to local entity (Element or Side)
in	ae	Local matrix
in,out	A	Global matrix

void element_assembly (const E_ & e , const LocalMatrix< T_, N_, N_ > & ae , SkSMatrix< T_ > & A)

Assemble local matrix into global symmetric skyline matrix.

Parameters

in	e	Reference to local entity (Element or Side)
in	ae	Local matrix
in,out	A	Global matrix

void element_assembly (const E_ & e , const LocalMatrix< T_, N_, N_ > & ae , SpMatrix< T_ > & A)

Assemble local matrix into global sparse matrix.

Parameters

in	e	Reference to local entity (Element or Side)
in	ae	Local matrix
in,out	A	Global matrix

void side_assembly (const Element & e , const LocalMatrix< T_, N_, N_ > & ae , SpMatrix< T_ > & A)

Side assembly of local matrix into global matrix (as instance of class [SpMatrix](#)).

Parameters

in	e	Reference to local Element
in	ae	Local matrix
in,out	A	Global matrix

void side_assembly (const Element & e , const LocalMatrix< T_, N_, N_ > & ae , SkSMatrix< T_ > & A)

Side assembly of local matrix into global matrix (as instance of class [SkSMatrix](#)).

Parameters

in	e	Reference to local Element
in	ae	Local matrix
in,out	A	Global matrix

void side_assembly (const Element & e , const LocalMatrix< T_, N_, N_ > & ae , SkMatrix< T_ > & A)

[Side](#) assembly of local matrix into global matrix (as instance of class [SkMatrix](#)).

Parameters

in	e	Reference to local Element
in	ae	Local matrix
in,out	A	Global matrix

void side_assembly (const Element & e , const LocalVect< T_, N_ > & be , Vect< T_ > & b)

Side assembly of local vector into global vector.

Parameters

in	e	Reference to local Element
in	be	Local vector
in,out	b	Global vector

5.2 Conservation Law Equations

For solvers of conservation law equations.

Classes

- class [ICPG1D](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D.
- class [ICPG2DT](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D.
- class [ICPG3DT](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D.
- class [LCL1D](#)
Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.
- class [LCL2DT](#)
Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.
- class [LCL3DT](#)
Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.
- class [Muscl](#)
Parent class for hyperbolic solvers with Muscl scheme.
- class [Muscl1D](#)
Class for 1-D hyperbolic solvers with [Muscl](#) scheme.
- class [Muscl2DT](#)
Class for 2-D hyperbolic solvers with [Muscl](#) scheme.
- class [Muscl3DT](#)
Class for 3-D hyperbolic solvers with [Muscl](#) scheme using tetrahedra.

5.2.1 Detailed Description

For solvers of conservation law equations.

5.3 Electromagnetics

Gathers electromagnetic equation classes.

Classes

- class [BiotSavart](#)
Class to compute the magnetic induction from the current density using the Biot-Savart formula.
- class [EC2D1T3](#)
Eddy current problems in 2-D domains using solenoidal approximation.
- class [Equa_Electromagnetics](#)< [T_](#), [NEN_](#), [NEE_](#), [NSN_](#), [NSE_](#) >
Abstract class for Electromagnetics [Equation](#) classes.
- class [HelmholtzBT3](#)
Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.

5.3.1 Detailed Description

Gathers electromagnetic equation classes.

5.4 Fluid Dynamics

Gathers Fluid Dynamics equation classes.

Classes

- class [Equa_Fluid](#)< T_, NEN_, NEE_, NSN_, NSE_ >
Abstract class for Fluid Dynamics [Equation](#) classes.
- class [NSP2DQ41](#)
Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using Q_1/P_0 element and a penalty formulation for the incompressibility condition.
- class [TINS2DT3B](#)
Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

5.4.1 Detailed Description

Gathers Fluid Dynamics equation classes.

5.5 Interface Problems

Gathers classes and functions for general interface problems, including image processing.

Classes

- class [FastMarching2D](#)
To run a Fast Marching Method on 2-D structured uniform grids.
- class [FMMSolver](#)
The Fast Marching Method solver.

5.5.1 Detailed Description

Gathers classes and functions for general interface problems, including image processing.

5.6 Laplace equation

Gathers equation classes for the Laplace equation.

Classes

- class [Equa.Laplace< T_, NEN_, NEE_, NSN_, NSE_ >](#)
Abstract class for classes about the Laplace equation.
- class [Laplace1DL2](#)
To build element equation for a 1-D elliptic equation using the 2-Node line element (P_1).
- class [Laplace1DL3](#)
To build element equation for the 1-D elliptic equation using the 3-Node line (P_2).
- class [Laplace2DFVT](#)
To build and solve the Laplace equation using a standard Finite Volume method.
- class [Laplace2DMHRT0](#)
To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas RT_0).
- class [Laplace2DT3](#)
To build element equation for the Laplace equation using the 2-D triangle element (P_1).
- class [SteklovPoincare2DBE](#)
Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.

5.6.1 Detailed Description

Gathers equation classes for the Laplace equation.

5.7 Solid Mechanics

Gathers Solid Mechanics finite element equations related classes.

Classes

- class [Bar2DL2](#)
To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node.
- class [Beam3DL2](#)
To build element equations for 3-D beam equations using 2-node lines.
- class [Elas2DQ4](#)
To build element equations for 2-D linearized elasticity using 4-node quadrilaterals.
- class [Elas2DT3](#)
To build element equations for 2-D linearized elasticity using 3-node triangles.
- class [Elas3DH8](#)
To build element equations for 3-D linearized elasticity using 8-node hexahedra.
- class [Elas3DT4](#)
To build element equations for 3-D linearized elasticity using 4-node tetrahedra.
- class [Equa_Solid< T_, NEN_, NEE_, NSN_, NSE_ >](#)
Abstract class for Solid Mechanics Finite Element classes.

5.7.1 Detailed Description

Gathers Solid Mechanics finite element equations related classes.

5.8 Heat Transfer

Gathers Heat Transfer equation classes.

Classes

- class [DC1DL2](#)
Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements.
- class [DC2DT3](#)
Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.
- class [DC2DT6](#)
Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles.
- class [DC3DAT3](#)
Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles.
- class [DC3DT4](#)
Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra.
- class [Equa_Therm](#)< T_, NEN_, NEE_, NSN_, NSE_ >
Abstract class for Heat transfer Finite Element classes.
- class [PhaseChange](#)
This class enables defining phase change laws for a given material.

5.8.1 Detailed Description

Gathers Heat Transfer equation classes.

5.9 Input/Output

Gathers Input/Output utility classes.

Classes

- class [IOField](#)
Enables working with files in the XML Format.
- class [IPF](#)
To read project parameters from a file in [IPF](#) format.
- class [Prescription](#)
To prescribe various types of data by an algebraic expression. Data may consist in boundary conditions, forces, tractions, fluxes, initial condition. All these data types can be defined through an enumerated variable.

Macros

- `#define MAX_NB_PAR 50`
Maximum number of parameters.
- `#define MAX_ARRAY_SIZE 100`
Maximum array size.
- `#define MAX_INPUT_STRING_LENGTH 100`
Maximum string length.
- `#define FILENAME_LENGTH 150`
Length of a string defining a file name.

5.9.1 Detailed Description

Gathers Input/Output utility classes.

5.9.2 Macro Definition Documentation

`#define MAX_NB_PAR 50`

Maximum number of parameters.
Used in class IPF

`#define MAX_ARRAY_SIZE 100`

Maximum array size.
Used in class IPF

`#define MAX_INPUT_STRING_LENGTH 100`

Maximum string length.
Used in class IPF

5.10 Utilities

Gathers utility functions and classes.

Files

- file [OFELI.h](#)
Header file that includes all kernel classes of the library.
- file [OFELI.Config.h](#)
File that contains some macros.
- file [constants.h](#)
File that contains some widely used constants.

Classes

- class [Func](#)
A simple class to parse real valued functions.
- class [Tabulation](#)
To read and manipulate tabulated functions.
- class [UserData< T_ >](#)
Abstract class to define by user various problem data.
- class [Point< T_ >](#)
Defines a point with arbitrary type coordinates.
- class [Point2D< T_ >](#)
Defines a 2-D point with arbitrary type coordinates.
- class [Gauss](#)
Calculate data for Gauss integration.
- class [Timer](#)
To handle elapsed time counting.

Macros

- `#define OFELI_E 2.71828182845904523536028747135`
- `#define OFELI_PI 3.14159265358979323846264338328`
- `#define OFELI_THIRD 0.33333333333333333333333333333333`
- `#define OFELI_SIXTH 0.16666666666666666666666666666667`
- `#define OFELI_TWELVETH 0.08333333333333333333333333333333`
- `#define OFELI_SQRT2 1.41421356237309504880168872421`
- `#define OFELI_SQRT3 1.73205080756887729352744634151`
- `#define OFELI_ONEOVERPI 0.31830988618379067153776752675`
- `#define OFELI_GAUSS2 0.57735026918962576450914878050196`
- `#define OFELI_EPSMCH DBL_EPSILON`
- `#define OFELI_TOLERANCE OFELI_EPSMCH*10000`
- `#define OFELI_IMAG std::complex<double>(0.,1.);`
- `#define PARSE(exp, var) theParser.Parse(exp,var)`
- `#define EVAL(d) theParser.Eval(d)`

Typedefs

- typedef unsigned long `lsize_t`
This type stands for type `unsigned long`.
- typedef double `real_t`
This type stands for `double`.
- typedef std::complex< double > `complex_t`
This type stands for type `std::complex<double>`

Functions

- ostream & `operator<<` (ostream &s, const `complex_t` &x)
Output a complex number.
- ostream & `operator<<` (ostream &s, const std::string &c)
Output a string.
- template<class T_ >
ostream & `operator<<` (ostream &s, const vector< T_ > &v)
Output a vector instance.
- template<class T_ >
ostream & `operator<<` (ostream &s, const std::pair< T_, T_ > &a)
Output a pair instance.
- void `saveField` (Vect< `real_t` > &v, string output_file, int opt)
Save a vector to an output file in a given file format.
- void `saveField` (PETScVect< `real_t` > &v, string output_file, int opt)
Save a PETSc vector to an output file in a given file format.
- void `saveField` (PETScVect< `real_t` > &v, const Mesh &mesh, string output_file, int opt)
Save a PETSc vector to an output file in a given file format.
- void `saveField` (Vect< `real_t` > &v, const Grid &g, string output_file, int opt)
Save a vector to an output file in a given file format, for a structured grid data.
- void `saveGnuplot` (string input_file, string output_file, string mesh_file)
Save a vector to an input `Gnuplot` file.
- void `saveTecplot` (string input_file, string output_file, string mesh_file)
Save a vector to an output file to an input `Tecplot` file.
- void `saveVTK` (string input_file, string output_file, string mesh_file)
Save a vector to an output `VTK` file.
- void `saveGmsh` (string input_file, string output_file, string mesh_file)
Save a vector to an output `Gmsh` file.
- ostream & `operator<<` (ostream &s, const Tabulation &t)
Output Tabulated function data.
- template<class T_ >
bool `operator==` (const Point< T_ > &a, const Point< T_ > &b)
Operator ==
- template<class T_ >
Point< T_ > `operator+` (const Point< T_ > &a, const Point< T_ > &b)
Operator +
- template<class T_ >
Point< T_ > `operator+` (const Point< T_ > &a, const T_ &x)
Operator +

- `template<class T_>`
`Point< T_ > operator-` (`const Point< T_ > &a`)
Unary Operator -
- `template<class T_>`
`Point< T_ > operator-` (`const Point< T_ > &a, const Point< T_ > &b`)
Operator -
- `template<class T_>`
`Point< T_ > operator-` (`const Point< T_ > &a, const T_ &x`)
Operator -
- `template<class T_>`
`Point< T_ > operator*` (`const T_ &a, const Point< T_ > &b`)
*Operator **
- `template<class T_>`
`Point< T_ > operator*` (`const int &a, const Point< T_ > &b`)
*Operator *.*
- `template<class T_>`
`Point< T_ > operator*` (`const Point< T_ > &b, const T_ &a`)
Operator /
- `template<class T_>`
`Point< T_ > operator*` (`const Point< T_ > &b, const int &a`)
*Operator **
- `template<class T_>`
`T_ operator*` (`const Point< T_ > &a, const Point< T_ > &b`)
*Operator **
- `template<class T_>`
`Point< T_ > operator/` (`const Point< T_ > &b, const T_ &a`)
Operator /
- `bool areClose` (`const Point< double > &a, const Point< double > &b, double toler=OFELI-TOLERANCE`)
Return `true` if both instances of class `Point<double>` are distant with less then `toler`
- `double SqrDistance` (`const Point< double > &a, const Point< double > &b`)
Return squared euclidean distance between points `a` and `b`
- `double Distance` (`const Point< double > &a, const Point< double > &b`)
Return euclidean distance between points `a` and `b`
- `template<class T_>`
`std::ostream & operator<<` (`std::ostream &s, const Point< T_ > &a`)
Output point coordinates.
- `template<class T_>`
`bool operator==` (`const Point2D< T_ > &a, const Point2D< T_ > &b`)
Operator ==.
- `template<class T_>`
`Point2D< T_ > operator+` (`const Point2D< T_ > &a, const Point2D< T_ > &b`)
Operator +.
- `template<class T_>`
`Point2D< T_ > operator+` (`const Point2D< T_ > &a, const T_ &x`)
Operator +.
- `template<class T_>`
`Point2D< T_ > operator-` (`const Point2D< T_ > &a`)

Unary Operator -

- `template<class T_ >`
`Point2D< T_ >` **operator-** (const `Point2D< T_ >` &a, const `Point2D< T_ >` &b)

Operator -

- `template<class T_ >`
`Point2D< T_ >` **operator-** (const `Point2D< T_ >` &a, const `T_` &x)

*Operator **

- `template<class T_ >`
`Point2D< T_ >` **operator*** (const `T_` &a, const `Point2D< T_ >` &b)

*Operator *.*

- `template<class T_ >`
`Point2D< T_ >` **operator*** (const `int` &a, const `Point2D< T_ >` &b)
- `template<class T_ >`
`Point2D< T_ >` **operator*** (const `Point2D< T_ >` &b, const `T_` &a)

Operator /

- `template<class T_ >`
`Point2D< T_ >` **operator*** (const `Point2D< T_ >` &b, const `int` &a)

*Operator **

- `template<class T_ >`
`T_` **operator*** (const `Point2D< T_ >` &b, const `Point2D< T_ >` &a)

*Operator *.*

- `template<class T_ >`
`Point2D< T_ >` **operator/** (const `Point2D< T_ >` &b, const `T_` &a)

Operator /

- `bool areClose` (const `Point2D< real_t >` &a, const `Point2D< real_t >` &b, `real_t` toler=`OFELI.TOLERANCE`)

Return `true` if both instances of class `Point2D<real_t>` are distant with less then toler [Default: `OFELI.EPSMCH`].

- `real_t SqrDistance` (const `Point2D< real_t >` &a, const `Point2D< real_t >` &b)

Return squared euclidean distance between points `a` and `b`

- `real_t Distance` (const `Point2D< real_t >` &a, const `Point2D< real_t >` &b)

Return euclidean distance between points `a` and `b`

- `template<class T_ >`
`std::ostream &` **operator<<** (`std::ostream &s`, const `Point2D< T_ >` &a)

Output point coordinates.

- `void getMesh` (string file, `ExternalFileFormat` form, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a mesh file stored in an external file format.

- `void getBamg` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a mesh file stored in `Bamg` format.

- `void getEasymesh` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a mesh file stored in `Easymesh` format.

- `void getGambit` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a mesh file stored in `Gambit` neutral format.

- `void getGmsh` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a mesh file stored in `Gmsh` format.

- `void getMatlab` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

Construct an instance of class `Mesh` from a Matlab mesh data.

- `void getNetgen` (string file, `Mesh &mesh`, `size_t nb_dof=1`)

- Construct an instance of class `Mesh` from a mesh file stored in `Netgen` format.

 - void `getTetgen` (string file, Mesh &mesh, size_t nb_dof=1)
- Construct an instance of class `Mesh` from a mesh file stored in `Tetgen` format.

 - void `getTriangle` (string file, Mesh &mesh, size_t nb_dof=1)
- Construct an instance of class `Mesh` from a mesh file stored in `Triangle` format.

 - void `saveMesh` (const string &file, const Mesh &mesh, ExternalFileFormat form)
- This function saves mesh data a file for a given external format.

 - void `saveGmsh` (const string &gp_file, const Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `Gmsh` format.

 - void `saveGnuplot` (const string &file, const Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `Gmsh` format.

 - void `saveMatlab` (const string &file, const Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `Matlab` format.

 - void `saveTecplot` (const string &file, const Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `Tecplot` format.

 - void `saveVTK` (const string &file, const Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `VTK` format.

 - void `saveBamg` (const string &file, Mesh &mesh)
- This function outputs a `Mesh` instance in a file in `Bamg` format.

 - void `BSpline` (size_t n, size_t t, Vect< Point< real_t > > &control, Vect< Point< real_t > > &output, size_t num_output)
- Function to perform a B-spline interpolation.

 - void `banner` (const string &prog=" ")
- Outputs a banner as header of any developed program.

 - template<class T_ >
void `QuickSort` (std::vector< T_ > &a, int begin, int end)
- Function to sort a vector.

 - template<class T_ >
void `qksort` (std::vector< T_ > &a, int begin, int end)
- Function to sort a vector.

 - template<class T_ , class C_ >
void `qksort` (std::vector< T_ > &a, int begin, int end, C_ compare)
- Function to sort a vector according to a key function.

 - int `Sgn` (real_t a)
- Return sign of a : -1 or 1.

 - real_t `Abs2` (complex_t a)
- Return square of modulus of complex number a

 - real_t `Abs2` (real_t a)
- Return square of real number a

 - real_t `Abs` (real_t a)
- Return absolute value of a

 - real_t `Abs` (complex_t a)
- Return modulus of complex number a

 - real_t `Abs` (const Point< real_t > &p)
- Return Norm of vector a

 - real_t `Conjg` (real_t a)
- Return complex conjugate of real number a

- `complex.t Conjg (complex.t a)`
Return complex conjugate of complex number *a*
- `real.t Max (real.t a, real.t b, real.t c)`
Return maximum value of real numbers *a*, *b* and *c*
- `int Max (int a, int b, int c)`
Return maximum value of integer numbers *a*, *b* and *c*
- `real.t Min (real.t a, real.t b, real.t c)`
Return minimum value of real numbers *a*, *b* and *c*
- `int Min (int a, int b, int c)`
Return minimum value of integer numbers *a*, *b* and *c*
- `real.t Max (real.t a, real.t b, real.t c, real.t d)`
Return maximum value of integer numbers *a*, *b*, *c* and *d*
- `int Max (int a, int b, int c, int d)`
Return maximum value of integer numbers *a*, *b*, *c* and *d*
- `real.t Min (real.t a, real.t b, real.t c, real.t d)`
Return minimum value of real numbers *a*, *b*, *c* and *d*
- `int Min (int a, int b, int c, int d)`
Return minimum value of integer numbers *a*, *b*, *c* and *d*
- `real.t Arg (complex.t x)`
Return argument of complex number *x*
- `complex.t Log (complex.t x)`
Return principal determination of logarithm of complex number *x*
- `template<class T_>`
`T_ Sqr (T_ x)`
Return square of value *x*
- `template<class T_>`
`void Scale (T_ a, const vector< T_ > &x, vector< T_ > &y)`
Multiply vector *x* by *a* and save result in vector *y*
- `template<class T_>`
`void Scale (T_ a, const Vect< T_ > &x, Vect< T_ > &y)`
Multiply vector *x* by *a* and save result in vector *y*
- `template<class T_>`
`void Scale (T_ a, vector< T_ > &x)`
Multiply vector *x* by *a*
- `template<class T_>`
`void Xpy (size_t n, T_ *x, T_ *y)`
Add array *x* to *y*
- `template<class T_>`
`void Xpy (const vector< T_ > &x, vector< T_ > &y)`
Add vector *x* to *y*
- `template<class T_>`
`void Axy (size_t n, T_ a, T_ *x, T_ *y)`
Multiply array *x* by *a* and add result to *y*
- `template<class T_>`
`void Axy (T_ a, const vector< T_ > &x, vector< T_ > &y)`
Multiply vector *x* by *a* and add result to *y*
- `template<class T_>`
`void Axy (T_ a, const Vect< T_ > &x, Vect< T_ > &y)`

- Multiply vector x by a and add result to y*

 - `template<class T_ >`
`void Copy (size_t n, T_ *x, T_ *y)`
Copy array x to y n is the arrays size.
 - `real_t Error2 (const vector< real_t > &x, const vector< real_t > &y)`
Return absolute L2 error between vectors x and y
 - `real_t RError2 (const vector< real_t > &x, const vector< real_t > &y)`
Return absolute L^2 error between vectors x and y
 - `real_t ErrorMax (const vector< real_t > &x, const vector< real_t > &y)`
Return absolute Max. error between vectors x and y
 - `real_t RErrorMax (const vector< real_t > &x, const vector< real_t > &y)`
Return relative Max. error between vectors x and y
 - `template<class T_ >`
`T_ Dot (size_t n, T_ *x, T_ *y)`
Return dot product of arrays x and y
 - `real_t Dot (const vector< real_t > &x, const vector< real_t > &y)`
Return dot product of vectors x and y .
 - `real_t Dot (const Vect< real_t > &x, const Vect< real_t > &y)`
Return dot product of vectors x and y
 - `template<class T_ >`
`T_ Dot (const Point< T_ > &x, const Point< T_ > &y)`
Return dot product of x and y
 - `template<class T_ >`
`void Assign (vector< T_ > &v, const T_ &a)`
Assign the value a to all entries of a vector v
 - `template<class T_ >`
`void Clear (vector< T_ > &v)`
Assign 0 to all entries of a vector.
 - `template<class T_ >`
`void Clear (Vect< T_ > &v)`
Assign 0 to all entries of a vector.
 - `real_t Nrm2 (size_t n, real_t *x)`
Return 2-norm of array x
 - `real_t Nrm2 (const vector< real_t > &x)`
Return 2-norm of vector x
 - `template<class T_ >`
`real_t Nrm2 (const Point< T_ > &a)`
Return 2-norm of a
 - `bool Equal (real_t x, real_t y, real_t toler=OFELLEPSMCH)`
Function to return true if numbers x and y are close up to a given tolerance $toler$
 - `char itoc (int i)`
Function to convert an integer to a character.
 - `string itos (int i)`
Function to convert an integer to a string.
 - `std::string itos (size_t i)`
Function to convert an integer to a string.
 - `string dtos (real_t d)`

Function to convert a real to a string.

- `template<class T_ >`
`T_ stringTo (const std::string &s)`

Function to convert a string to a template type parameter.

- `void RTrim (char *s)`

Function to remove blanks at the end of a string.

- `void LTrim (char *s)`

Function to remove blanks at the beginning of a string.

- `void Trim (char *s)`

Function to remove blanks at the beginning and end of a string.

- `template<class T_ >`
`void Swap (T_ &a, T_ &b)`

Swap elements a and b.

5.10.1 Detailed Description

Gathers utility functions and classes.

5.10.2 Macro Definition Documentation

#define OFELI_E 2.71828182845904523536028747135

Value of e or exp (with 28 digits)

#define OFELI_PI 3.14159265358979323846264338328

Value of Pi (with 28 digits)

#define OFELI_THIRD 0.333333333333333333333333333333

Value of $1/3$ (with 28 digits)

#define OFELI_SIXTH 0.166666666666666666666666666667

Value of $1/6$ (with 28 digits)

#define OFELI_TWELVETH 0.083333333333333333333333333333

Value of $1/12$ (with 28 digits)

#define OFELI_SQRT2 1.41421356237309504880168872421

Value of $\sqrt{2}$ (with 28 digits)

#define OFELI_SQRT3 1.73205080756887729352744634151

Value of $\sqrt{3}$ (with 28 digits)

#define OFELI_ONEOVERPI 0.31830988618379067153776752675

Value of $1/Pi$ (with 28 digits)

#define OFELI_GAUSS2 0.57735026918962576450914878050196

Value of $1/\sqrt{3}$ (with 32 digits)

#define OFELI_EPSMCH DBL_EPSILON

Value of Machine Epsilon

#define OFELI_TOLERANCE OFELI_EPSMCH*10000

Default tolerance for an iterative process = OFELI_EPSMCH * 10000

#define OFELI_IMAG std::complex<double>(0.,1.);

= Unit imaginary number (i)

#define PARSE(exp, var) theParser.Parse(exp,var)

A macro that parses a regular expression *exp* using the variables in the string *var*. For instance, to parse the function $\sin(x+y)$ one must declare `PARSE("sin(x+y)","x,y")`

#define EVAL(d) theParser.Eval(d)

A macro that evaluates a parsed regular expression For instance, with a declaration `PARSE("sin(x+y)","x,y")` the data $x=1$ and $y=2$ using this function must be evaluated as follows: `EVAL(d)` with $d[0]=1$, $d[1]=2$

5.10.3 Function Documentation

void saveField (Vect< real.t > &v, string output_file, int opt)

Save a vector to an output file in a given file format.

Case where the vector contains mesh information

Parameters

in	<i>v</i>	Vect instance to save
in	<i>output_file</i>	Output file where to save the vector
in	<i>opt</i>	Option to choose file format to save. This is to be chosen among enumerated values: GMSH GNUPLOT MATLAB TECPLOT VTK

void saveField (PETScVect< real.t > &v, string output_file, int opt)

Save a PETSc vector to an output file in a given file format.

Case where the vector does not contain mesh information

Parameters

in	<i>v</i>	PETScVect instance to save
in	<i>output_file</i>	Output file where to save the vector
in	<i>opt</i>	Option to choose file format to save. This is to be chosen among enumerated values: GMSH, GNUPLOT, MATLAB, TECPLOT, VTK

void saveField (PETScVect< real.t > &v, const Mesh &mesh, string output_file, int opt)

Save a PETSc vector to an output file in a given file format.

Case where the vector does not contain mesh information

Parameters

in	<i>v</i>	PETScVect instance to save
in	<i>mesh</i>	Mesh instance
in	<i>output_file</i>	Output file where to save the vector
in	<i>opt</i>	Option to choose file format to save. This is to be chosen among enumerated values: GMSH, GNUPLOT, MATLAB, TECPLOT, VTK

void saveField (Vect< real.t > &v, const Grid &g, string output_file, int opt = VTK)

Save a vector to an output file in a given file format, for a structured grid data.

Parameters

in	<i>v</i>	Vect instance to save
in	<i>g</i>	Grid instance
in	<i>output_file</i>	Output file where to save the vector
in	<i>opt</i>	Option to choose file format to save. This is to be chosen among enumerated values: VTK

void saveGnuplot (string input_file, string output_file, string mesh_file)

Save a vector to an input [Gnuplot](#) file.

Gnuplot is a command-line driven program for producing 2D and 3D plots. It is under the GNU General Public License. Available information can be found in the site:

<http://www.gnuplot.info/>

Parameters

in	<i>input_file</i>	Input file (OFELI XML file containing a field).
in	<i>output_file</i>	Output file (gnuplot format file)
in	<i>mesh_file</i>	File containing mesh data

void saveTecplot (string input_file, string output_file, string mesh_file)

Save a vector to an output file to an input [Tecplot](#) file.

Tecplot is high quality post graphical commercial processing program developed by [Amtec](#). Available information can be found in the site: <http://www.tecplot.com>

Parameters

in	<i>input_file</i>	Input file (OFELI XML file containing a field).
in	<i>output_file</i>	Output file (gnuplot format file)
in	<i>mesh_file</i>	File containing mesh data

saveVTK (string input_file, string output_file, string mesh_file)

Save a vector to an output [VTK](#) file.

The Visualization ToolKit (VTK) is an open source, freely available software system for 3D computer graphics. Available information can be found in the site:

<http://public.kitware.com/VTK/>

Parameters

in	<i>input_file</i>	Input file (OFELI XML file containing a field).
in	<i>output_file</i>	Output file (VTK format file)
in	<i>mesh_file</i>	File containing mesh data

void saveGmsh (string *input_file*, string *output_file*, string *mesh_file*)

Save a vector to an output Gmsh file.

Gmsh is a free mesh generator and postprocessor that can be downloaded from the site:

<http://www.geuz.org/gmsh/>

Parameters

in	<i>input_file</i>	Input file (OFELI XML file containing a field).
in	<i>output_file</i>	Output file (Gmsh format file)
in	<i>mesh_file</i>	File containing mesh data

bool operator== (const Point< T_ > & a, const Point< T_ > & b)

Operator ==

Return true if a=b, false if not.

Point< T_ > operator+ (const Point< T_ > & a, const Point< T_ > & b)

Operator +

Return sum of two points a and b

Point< T_ > operator+ (const Point< T_ > & a, const T_ & x)

Operator +

Translate a by x

Point< T_ > operator- (const Point< T_ > & a)

Unary Operator -

Return minus a

Point< T_ > operator- (const Point< T_ > & a, const Point< T_ > & b)

Operator -

Return point a minus point b

Point< T_ > operator- (const Point< T_ > & a, const T_ & x)

Operator -

Translate a by -x

Point< T_ > operator* (const T_ & a, const Point< T_ > & b)

Operator *

Return point b premultiplied by constant a

Point< T_ > operator* (const int & a, const Point< T_ > & b)

Operator *.

Return point b divided by integer constant a

Point< T_ > operator* (const Point< T_ > & b, const T_ & a)

Operator /

Return point b multiplied by constant a

Point< T_ > operator* (const Point< T_ > & b, const int & a)

Operator *

Return point b postmultiplied by constant a

T_ operator* (const Point< T_ > & b, const Point< T_ > & a)

Operator *

Return inner (scalar) product of points a and b

Point< T_ > operator/ (const Point< T_ > & b, const T_ & a)

Operator /

Return point b divided by constant a

bool operator== (const Point2D< T_ > & a, const Point2D< T_ > & b)

Operator ==.

Return true if a=b, false if not.

Point2D< T_ > operator+ (const Point2D< T_ > & a, const Point2D< T_ > & b)

Operator +.

Return sum of two points a and b

Point2D< T_ > operator+ (const Point2D< T_ > & a, const T_ & x)

Operator +.

Translate a by x

Point2D< T_ > operator- (const Point2D< T_ > & a)

Unary Operator -

Return minus a

Point2D< T_ > operator- (const Point2D< T_ > & a, const Point2D< T_ > & b)

Operator -

Return point a minus point b

Point2D< T_ > operator- (const Point2D< T_ > & a, const T_ & x)

Operator -

Translate a by -x

Point2D< T_ > operator* (const T_ & *a*, const Point2D< T_ > & *b*)

Operator *.

Return point *b* premultiplied by constant *a*

Point2D< T_ > operator* (const int & *a*, const Point2D< T_ > & *b*)

Operator *.

Return point *b* divided by integer constant *a*

Point2D< T_ > operator* (const Point2D< T_ > & *b*, const T_ & *a*)

Operator /

Return point *b* postmultiplied by constant *a*

Point2D< T_ > operator* (const Point2D< T_ > & *b*, const int & *a*)

Operator *

Return point *b* postmultiplied by constant *a*

T_ operator* (const Point2D< T_ > & *b*, const Point2D< T_ > & *a*)

Operator *.

Return point *b* postmultiplied by integer constant *a*.

Point2D< T_ > operator/ (const Point2D< T_ > & *b*, const T_ & *a*)

Operator /

Return point *b* divided by constant *a*

void getMesh (string *file*, ExternalFileFormat *form*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in an external file format.

Parameters

in	<i>file</i>	Input mesh file name.
in	<i>form</i>	Format of the mesh file. This one can be chosen among the enumerated values: <ul style="list-style-type: none"> • GMSH: Mesh generator Gmsh, see site: http://www.geuz.org/gmsh/ • MATLAB: Matlab file, see site: http://www.mathworks.com/products/matlab/ • EASYMESH: Easymesh is a 2-D mesh generator, see site: http://web.mit.edu/easymesh.v1.4/www/easymesh.html • GAMBIT: Gambit is a mesh generator associated to Fluent http://www.stanford.edu/class/me469b/gambit_download.html • BAMG: Mesh generator Bamg, see site: http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html • NETGEN: Netgen is a 3-D mesh generator, see site: http://www.hpfem.jku.at/netgen/ • TETGEN: Tetgen is a 3-D mesh generator, see site: http://tetgen.berlios.de/ • TRIANGLE_FF: Triangle is a 2-D mesh generator, see site: http://www.cs.cmu.edu/~quake/triangle.html
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getBamg (string *file*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in **Bamg** format.

Parameters

in	<i>file</i>	Name of a file written in the Bamg format.
----	-------------	--

Note

Bamg is a 2-D mesh generator. It allows to construct adapted meshes from a given metric. It was developed at INRIA, France. Available information can be found in the site:

<http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html>

Parameters

out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getEasymesh (string file, Mesh & mesh, size_t nb_dof = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in [Easymesh](#) format.

Parameters

in	<i>file</i>	Name of a file (without extension) written in Easymesh format. Actually, the function <code>Easymesh2MDF</code> attempts to read mesh data from files <code>file.e</code> , <code>file.n</code> and <code>file.s</code> produced by Easymesh .
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Note

Easymesh is a free program that generates 2-D, unstructured, Delaunay and constrained Delaunay triangulations in general domains. It can be downloaded from the site:

<http://www.dinma.univ.trieste.it/nirftc/research/easymesh/Default.htm>

Parameters

in	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getGambit (string file, Mesh & mesh, size_t nb_dof = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in **Gambit** neutral format.

Note

Gambit is a commercial mesh generator associated to the CFD code [Fluent](#). Informations about **Gambit** can be found in the site:

<http://www.fluent.com/software/gambit/>

Parameters

in	<i>file</i>	Name of a file written in the Gambit neutral format.
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getGmsh (string file, Mesh & mesh, size_t nb_dof = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in [Gmsh](#) format.

Note

Gmsh is a free mesh generator that can be downloaded from the site:

<http://www.geuz.org/gmsh/>

Parameters

in	<i>file</i>	Name of a file written in the Gmsh format.
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getMatlab (string *file*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class [Mesh](#) from a Matlab mesh data.

Note

Matlab is a language of scientific computing including visualization. It is developed by [MathWorks](#). Available information can be found in the site:
<http://www.mathworks.com/products/matlab/>

Parameters

in	<i>file</i>	Name of a file created by Matlab by executing the script file <code>Matlab20FELI.m</code>
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getNetgen (string *file*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in **Netgen** format.

Note

Netgen is a tetrahedral mesh generator that can be downloaded from the site:
<http://www.hpfem.jku.at/netgen/>

Parameters

in	<i>file</i>	Name of a file written in the Netgen format.
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. [default = 1]

void getTetgen (string *file*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class [Mesh](#) from a mesh file stored in **Tetgen** format.

Note

Tetgen is a free three-dimensional mesh generator that can be downloaded in the site:
<http://tetgen.berlios.de/>

Parameters

in	<i>file</i>	Name of a file written in the Tetgen format.
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void getTriangle (string *file*, Mesh & *mesh*, size_t *nb_dof* = 1)

Construct an instance of class **Mesh** from a mesh file stored in **Triangle** format.

Note

TRIANGLE is a C program that can generate meshes, Delaunay triangulations and Voronoi diagrams for 2D pointsets that can be downloaded in the site:

http://people.scs.fsu.edu/~burkardt/c_src/triangle/triangle.html/

Parameters

in	<i>file</i>	Name of a file written in the Tetgen format.
out	<i>mesh</i>	Mesh instance created by the function.
in	<i>nb_dof</i>	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. Its default value here is 1.

void saveMesh (const string & *file*, const Mesh & *mesh*, ExternalFileFormat *form*)

This function saves mesh data a file for a given external format.

Parameters

in	<i>file</i>	File where to store mesh
in	<i>mesh</i>	Mesh instance to save
in	<i>form</i>	Format of the mesh file. This one can be chosen among the enumerated values: <ul style="list-style-type: none"> • GMSH: Mesh generator and graphical postprocessor Gmsh: http://www.geuz.org/gmsh/ • GNUPLOT: Well known graphics software: http://www.gnuplot.info/ • MATLAB: Matlab file: http://www.mathworks.com/products/matlab/ • TECPLOT: Commercial graphics software: http://www.tecplot.com • VTK: Graphics format for the free postprocessor ParaView: http://public.kitware.com/VTK/

void saveGmsh (const string & *file*, const Mesh & *mesh*)

This function outputs a **Mesh** instance in a file in **Gmsh** format.

Note

Gmsh is a free mesh generator that can be downloaded from the site: <http://www.geuz.org/gmsh/>

Parameters

out	<i>file</i>	Output file in Gmsh format.
in	<i>mesh</i>	Mesh instance to save.

void saveGnuplot (const string &file, const Mesh & mesh)

This function outputs a [Mesh](#) instance in a file in **Gmsh** format.

Note

Gnuplot is a command-line driven program for producing 2D and 3D plots. It is under the GNU General Public License. Available information can be found in the site: <http://www.gnuplot.info/>

Parameters

out	<i>file</i>	Output file in Gnuplot format.
in	<i>mesh</i>	Mesh instance to save.

void saveMatlab (const string &file, const Mesh & mesh)

This function outputs a [Mesh](#) instance in a file in **Matlab** format.

Note

Matlab is a language of scientific computing including visualization. It is developed by **MathWorks**. Available information can be found in the site: <http://www.mathworks.com/products/matlab/>

Parameters

out	<i>file</i>	Output file in Matlab format.
in	<i>mesh</i>	Mesh instance to save.

void saveTecplot (const string &file, const Mesh & mesh)

This function outputs a [Mesh](#) instance in a file in **Tecplot** format.

Note

Tecplot is high quality post graphical commercial processing program developed by **Amtec**. Available information can be found in the site: <http://www.tecplot.com>

Parameters

out	<i>file</i>	Output file in Tecplot format.
in	<i>mesh</i>	Mesh instance to save.

void saveVTK (const string &file, const Mesh &mesh)

This function outputs a [Mesh](#) instance in a file in **VTK** format.

Note

The Visualization ToolKit (VTK) is an open source, freely available software system for 3D computer graphics. Available information can be found in the site:

<http://public.kitware.com/VTK/>

Parameters

out	<i>file</i>	Output file in VTK format.
in	<i>mesh</i>	Mesh instance to save.

void saveBamg (const string &file, Mesh &mesh)

This function outputs a [Mesh](#) instance in a file in **Bamg** format.

Parameters

in	<i>file</i>	Name of a file written in the Bamg format.
----	-------------	--

Note

Bamg is a 2-D mesh generator. It allows to construct adapted meshes from a given metric. It was developed at INRIA, France. Available information can be found in the site:

<http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html>

Parameters

in	<i>mesh</i>	Mesh instance.
----	-------------	--------------------------------

BSpline (size_t n, size_t t, Vect< Point< real_t > > &control, Vect< Point< real_t > > &output, size_t num_output)

Function to perform a B-spline interpolation.

This program is adapted from a free program distributed by Keith Vertanen (vertankd@cda.-mrs.umn.edu) in 1994.

Parameters

in	<i>n</i>	Number of control points minus 1.
in	<i>t</i>	Degree of the polynomial plus 1.
in	<i>control</i>	Control point array made up of Point structure.
out	<i>output</i>	Vector in which the calculated spline points are to be put.
in	<i>num_output</i>	How many points on the spline are to be calculated.

Note

Condition: $n+2 > t$ (No curve results if $n+2 \leq t$) Control vector contains the number of points specified by *n* Output array is the proper size to hold *num_output* point structures

void banner (const string & *prog* = " ")

Outputs a banner as header of any developed program.

Parameters

in	<i>prog</i>	Calling program name. Enables writing a copyright notice accompanying the program.
-----------	-------------	--

void QuickSort (std::vector< T_ > & a, int begin, int end)

Function to sort a vector.

qksort uses the famous quick sorting algorithm.

Parameters

in,out	<i>a</i>	Vector to sort.
in	<i>begin</i>	index of starting iterator
in	<i>end</i>	index of ending iterator

The calling program must provide an overloading of the operator < for the type T_.

void qksort (std::vector< T_ > & a, int begin, int end)

Function to sort a vector.

qksort uses the famous quick sorting algorithm.

Parameters

in,out	<i>a</i>	Vector to sort.
in	<i>begin</i>	index of starting index (default value is 0)
in	<i>end</i>	index of ending index (default value is the vector size - 1)

void qksort (std::vector< T_ > & a, int begin, int end, C_ compare)

Function to sort a vector according to a key function.

qksort uses the famous quick sorting algorithm.

Parameters

in,out	<i>a</i>	Vector to sort.
in	<i>begin</i>	index of starting index (0 for the beginning of the vector)
in	<i>end</i>	index of ending index
in	<i>compare</i>	A function object that implements the ordering. The user must provide this function that returns a boolean function that is true if the first argument is less than the second and false if not.

void Scale (T_ a, const vector< T_ > & x, vector< T_ > & y)

Multiply vector x by a and save result in vector y

x and y are instances of class vector<T_>

void Scale (T_ a, const Vect< T_ > & x, Vect< T_ > & y)

Multiply vector x by a and save result in vector y

x and y are instances of class Vect<T_>

void Scale (T_ a, vector< T_ > & x)

Multiply vector x by a

x is an instance of class vector<T_>

void Xpy (const vector< T_ > & x, vector< T_ > & y)

Add vector x to y

x and y are instances of class vector<T_>

void Axy (size_t n, T_ a, T_ * x, T_ * y)

Multiply array x by a and add result to y

n is the arrays size.

void Axy (T_ a, const vector< T_ > & x, vector< T_ > & y)

Multiply vector x by a and add result to y

x and y are instances of class vector<T_>

void Axy (T_ a, const Vect< T_ > & x, Vect< T_ > & y)

Multiply vector x by a and add result to y

x and y are instances of class Vect<T_>

T_ Dot (size_t n, T_ * x, T_ * y)

Return dot product of arrays x and y

n is the arrays size.

double Dot (const vector< real_t > & x, const vector< real_t > & y)

Return dot product of vectors x and y.

x and y are instances of class vector<double>

real_t Dot (const Vect< real_t > & x, const Vect< real_t > & y)

Return dot product of vectors x and y

x and y are instances of class Vect<T_>

void Clear (vector< T_ > & v)

Assign 0 to all entries of a vector.

Parameters

in	v	Vector to clear
----	---	-----------------

void Clear (Vect< T_ > & v)

Assign 0 to all entries of a vector.

Parameters

in	v	Vector to clear
----	---	-----------------

real_t Nrm2 (size_t n, real_t * x)

Return 2-norm of array x

Parameters

in	n	is Array length
in	x	Array to treat

bool Equal (real_t x , real_t y , real_t $toler = \text{OFELI_EPSMCH}$)

Function to return true if numbers x and y are close up to a given tolerance $toler$
Default value of tolerance is the constant `OFELI_EPSMCH`

5.11 Vector and Matrix

Gathers vector and matrix related classes.

Classes

- class [BMatrix< T_ >](#)
To handle band matrices.
- class [DMatrix< T_ >](#)
To handle dense matrices.
- class [DSMatrix< T_ >](#)
To handle symmetric dense matrices.
- class [LocalMatrix< T_, NR_, NC_ >](#)
Handles small size matrices like element matrices, with a priori known size.
- class [LocalVect< T_, N_ >](#)
Handles small size vectors like element vectors.
- class [PETScMatrix< T_ >](#)
To handle matrices in sparse storage format using the Petsc library.
- class [PETScVect< T_ >](#)
To handle general purpose vectors using Petsc.
- class [PETScWrapper< T_ >](#)
This class is a wrapper to be used when the library Petsc is installed and used with [OFELI](#).
- class [SkMatrix< T_ >](#)
To handle square matrices in skyline storage format.
- class [SkSMatrix< T_ >](#)
To handle symmetric matrices in skyline storage format.
- class [SpMatrix< T_ >](#)
To handle matrices in sparse storage format.
- class [TrMatrix< T_ >](#)
To handle tridiagonal matrices.
- class [Vect< T_ >](#)
To handle general purpose vectors.

Typedefs

- typedef Eigen::Matrix< T_,
Eigen::Dynamic, 1 > [VectorX](#)
This type is the vector type in the Eigen library.

Functions

- template<class T_ >
BMatrix< T_ > [operator*](#) (T_ a, const BMatrix< T_ > &a)
*Operator * (Premultiplication of matrix by constant)*
- template<class T_ >
ostream & [operator<<](#) (ostream &s, const BMatrix< T_ > &a)
Output matrix in output stream.
- template<class T_ >
ostream & [operator<<](#) (ostream &s, const DMatrix< T_ > &a)

Output matrix in output stream.

- `template<class T_,>`
`ostream & operator<< (ostream &s, const DSMatrix< T_ > &a)`
Output matrix in output stream.
- `template<class T_, size_t NR_, size_t NC_>`
`LocalMatrix< T_, NR_, NC_ > operator* (T_ a, const LocalMatrix< T_, NR_, NC_ > &x)`
*Operator * (Multiply matrix x by scalar a)*
- `template<class T_, size_t NR_, size_t NC_>`
`LocalMatrix< T_, NR_, NC_ > operator/ (T_ a, const LocalMatrix< T_, NR_, NC_ > &x)`
Operator / (Divide matrix x by scalar a)
- `template<class T_, size_t NR_, size_t NC_>`
`LocalMatrix< T_, NR_, NC_ > operator+ (const LocalMatrix< T_, NR_, NC_ > &x, const LocalMatrix< T_, NR_, NC_ > &y)`
Operator + (Add matrix x to y)
- `template<class T_, size_t NR_, size_t NC_>`
`LocalMatrix< T_, NR_, NC_ > operator- (const LocalMatrix< T_, NR_, NC_ > &x, const LocalMatrix< T_, NR_, NC_ > &y)`
Operator - (Subtract matrix y from x)
- `template<class T_, size_t NR_, size_t NC_>`
`ostream & operator<< (ostream &s, const LocalMatrix< T_, NR_, NC_ > &a)`
Output vector in output stream.
- `template<class T_, size_t N_>`
`LocalVect< T_, N_ > operator+ (const LocalVect< T_, N_ > &x, const LocalVect< T_, N_ > &y)`
Operator + (Add two vectors)
- `template<class T_, size_t N_>`
`LocalVect< T_, N_ > operator- (const LocalVect< T_, N_ > &x, const LocalVect< T_, N_ > &y)`
Operator - (Subtract two vectors)
- `template<class T_, size_t N_>`
`LocalVect< T_, N_ > operator* (T_ a, const LocalVect< T_, N_ > &x)`
*Operator * (Premultiplication of vector by constant)*
- `template<class T_, size_t N_>`
`LocalVect< T_, N_ > operator/ (T_ a, const LocalVect< T_, N_ > &x)`
Operator / (Division of vector by constant)
- `template<class T_, size_t N_>`
`real_t Dot (const LocalVect< T_, N_ > &a, const LocalVect< T_, N_ > &b)`
Calculate dot product of 2 vectors (instances of class `LocalVect`)
- `template<class T_, size_t N_>`
`void Scale (T_ a, const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`
Multiply vector x by constant a and store result in y .
- `template<class T_, size_t N_>`
`void Scale (T_ a, LocalVect< T_, N_ > &x)`
Multiply vector x by constant a and store result in x .
- `template<class T_, size_t N_>`
`void Axy (T_ a, const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`
*Add $a*x$ to vector y .*
- `template<class T_, size_t N_>`
`void Copy (const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`

Copy vector x into vector y .

- `template<class T_, size_t N_>`
`ostream & operator<< (ostream &s, const LocalVect< T_, N_ > &v)`

Output vector in output stream.

- `template<class T_ >`
`PETScVect< T_ > operator* (const PETScMatrix< T_ > &A, const PETScVect< T_ > &x)`
- `template<class T_ >`
`ostream & operator<< (ostream &s, PETScMatrix< T_ > &A)`

Output matrix in output stream.

- `template<class T_ >`
`ostream & operator<< (ostream &s, const PETScWrapper< T_ > &w)`

Output Petsc Wrapper data in output stream.

- `template<class T_ >`
`ostream & operator<< (ostream &s, const SkMatrix< T_ > &a)`

Output matrix in output stream.

- `template<class T_ >`
`ostream & operator<< (ostream &s, const SkSMatrix< T_ > &a)`

Output matrix in output stream.

- `template<class T_ >`
`ostream & operator<< (ostream &s, const SpMatrix< T_ > &A)`

- `template<class T_ >`
`TrMatrix< T_ > operator* (T_ a, const TrMatrix< T_ > &A)`

*Operator * (Premultiplication of matrix by constant)*

- `template<class T_ >`
`ostream & operator<< (ostream &s, const TrMatrix< T_ > &a)`

Output matrix in output stream.

- `real_t operator* (const vector< real_t > &x, const vector< real_t > &y)`

*Operator * (Dot product of 2 vector instances)*

Friends

- `template<class TT_ >`
`ostream & operator<< (ostream &s, const SpMatrix< TT_ > &A)`

5.11.1 Detailed Description

Gathers vector and matrix related classes.

5.11.2 Typedef Documentation

VectorX

This type is the vector type in the Eigen library.

Remarks

: This type is available only if the Eigen library was installed in conjunction with [OFELI](#)

5.11.3 Function Documentation

BMatrix< T_ > operator* (T_ a, const BMatrix< T_ > & A)

Operator * (Premultiplication of matrix by constant)

Returns

a*A

LocalMatrix< T_, NR_, NC_ > operator* (T_ a, const LocalMatrix< T_, NR_, NC_ > & x)

Operator * (Multiply matrix x by scalar a)

Returns

a*x

LocalMatrix< T_, NR_, NC_ > operator/ (T_ a, const LocalMatrix< T_, NR_, NC_ > & x)

Operator / (Divide matrix x by scalar a)

Returns

x/a

LocalMatrix< T_, NR_, NC_ > operator+ (const LocalMatrix< T_, NR_, NC_ > & x, const LocalMatrix< T_, NR_, NC_ > & y)

Operator + (Add matrix x to y)

Returns

x+y

LocalMatrix< T_, NR_, NC_ > operator- (const LocalMatrix< T_, NR_, NC_ > & x, const LocalMatrix< T_, NR_, NC_ > & y)

Operator - (Subtract matrix y from x)

Returns

x-y

LocalVect< T_, N_ > operator+ (const LocalVect< T_, N_ > & x, const LocalVect< T_, N_ > & y)

Operator + (Add two vectors)

Returns

x+y

LocalVect< T_, N_ > operator- (const LocalVect< T_, N_ > & x, const LocalVect< T_, N_ > & y)

Operator - (Subtract two vectors)

Returns

$x-y$

LocalVect< T_, N_ > operator* (T_ a, const LocalVect< T_, N_ > & x)

Operator * (Premultiplication of vector by constant)

Returns

$a*x$

LocalVect< T_, N_ > operator/ (T_ a, const LocalVect< T_, N_ > & x)

Operator / (Division of vector by constant)

Returns

x/a

double Dot (const LocalVect< T_, N_ > & a, const LocalVect< T_, N_ > & b)

Calculate dot product of 2 vectors (instances of class [LocalVect](#))

Returns

Dot product

PETScVect< T_ > operator* (const PETScMatrix< T_ > & A, const PETScVect< T_ > & x)

Multiply a matrix by a vector

Parameters

in	A	Matrix to multiply by (Instance of class PETScMatrix)
in	x	Vector to multiply by (Instance of class PETScVect)

Returns

Vector product $y = Ax$

ostream & operator<< (ostream & s, const SpMatrix< T_ > & A)

Output matrix in output stream

TrMatrix< T_ > operator* (T_ a, const TrMatrix< T_ > & A)

Operator * (Premultiplication of matrix by constant)

Returns

$a*A$

real_t operator* (const vector< real_t > & x, const vector< real_t > & y)

Operator * (Dot product of 2 vector instances)

Returns

$x \cdot y$

5.11.4 Friends

ostream & operator<< (ostream & s, const SpMatrix< TT_ > & A) [friend]

Output matrix in output stream

5.12 Physical properties of media

A module that contains classes for physical properties of materials and media.

Classes

- class [Material](#)

To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members.

5.12.1 Detailed Description

A module that contains classes for physical properties of materials and media.

5.13 Global Variables

Gathers all global variables in the library.

Variables

- Node * [theNode](#)
A pointer to [Node](#).
- Element * [theElement](#)
A pointer to [Element](#).
- Side * [theSide](#)
A pointer to [Side](#).
- Edge * [theEdge](#)
A pointer to [Edge](#).
- int [theStep](#)
Time step counter.
- int [theIteration](#)
Iteration counter.
- int [NbTimeSteps](#)
Number of time steps.
- int [MaxNbIterations](#)
Maximal number of iterations.
- int [Verbosity](#)
Parameter for verbosity of message outputting.
- [real.t theTimeStep](#)
Time step label.
- [real.t theTime](#)
Time value.
- [real.t theFinalTime](#)
Final time value.
- [real.t theTolerance](#)
Tolerance value for convergence.
- [real.t theDiscrepancy](#)
Value of discrepancy for an iterative procedure Its default value is 1.0.
- bool [Converged](#)
Boolean variable to say if an iterative procedure has converged.
- bool [InitPetsc](#)

5.13.1 Detailed Description

Gathers all global variables in the library.

5.13.2 Variable Documentation

Node* theNode

A pointer to [Node](#).

Useful for loops on nodes

Element* theElement

A pointer to [Element](#).

Useful for loops on elements

Side* theSide

A pointer to [Side](#).

Useful for loops on sides

Edge* theEdge

A pointer to [Edge](#).

Useful for loops on edges

int theStep

Time step counter.

This counter must be initialized by the user if the macro `timeLoop` is not used

Remarks

May be used in conjunction with the macro `TimeLoop`. In this case, it has to be initialized before. Its default value is 1

int theIteration

Iteration counter.

This counter must be initialized by the user

Remarks

May be used in conjunction with the macro `IterationLoop`. Its default value is 1

int NbTimeSteps

Number of time steps.

Remarks

May be used in conjunction with the macro `TimeLoop`.

int MaxNbIterations

Maximal number of iterations.

Remarks

May be used in conjunction with the macro `IterationLoop`. Its default value is 1000

int Verbosity

Parameter for verbosity of message outputting.

Its default value is 1

real t theTimeStep

Time step label.

Remarks

May be used in conjunction with the macro TimeLoop. In this case, it has to be initialized before

real t theTime

Time value.

Remarks

May be used in conjunction with the macro TimeLoop. Its default value is 0.0

real t theFinalTime

Final time value.

Remarks

May be used in conjunction with the macro TimeLoop. In this case, it has to be initialized before

real t theTolerance

Tolerance value for convergence.

Remarks

May be used within an iterative procedure. Its default value is 1.e-8

bool Converged

Boolean variable to say if an iterative procedure has converged.

Its default value is false

bool InitPetsc

Boolean to say if PETSc use was initialized. Useful only if PETSc is used

5.14 Finite Element Mesh

Gathers mesh related classes.

Classes

- class [Domain](#)
To store and treat finite element geometric information.
- class [Edge](#)
To describe an edge.
- class [Element](#)
To store and treat finite element geometric information.
- class [Figure](#)
To store and treat a figure (or shape) information.
- class [Rectangle](#)
To store and treat a rectangular figure.
- class [Brick](#)
To store and treat a brick (parallelepiped) figure.
- class [Circle](#)
To store and treat a circular figure.
- class [Sphere](#)
To store and treat a sphere.
- class [Ellipse](#)
To store and treat an ellipsoidal figure.
- class [Triangle](#)
To store and treat a triangle.
- class [Polygon](#)
To store and treat a polygonal figure.
- class [Grid](#)
To manipulate structured grids.
- class [Mesh](#)
To store and manipulate finite element meshes.
- class [MeshAdapt](#)
To adapt mesh in function of given solution.
- class [NodeList](#)
Class to construct a list of nodes having some common properties.
- class [ElementList](#)
Class to construct a list of elements having some common properties.
- class [SideList](#)
Class to construct a list of sides having some common properties.
- class [EdgeList](#)
Class to construct a list of edges having some common properties.
- class [Node](#)
To describe a node.
- class [Partition](#)
To partition a finite element mesh into balanced submeshes.
- class [Side](#)
To store and treat finite element sides (edges in 2-D or faces in 3-D)

Macros

- `#define GRAPH_MEMORY 1000000`
Memory necessary to store matrix graph.
- `#define MAX_NB_ELEMENTS 10000`
Maximal Number of elements.
- `#define MAX_NB_NODES 10000`
Maximal number of nodes.
- `#define MAX_NB_SIDES 30000`
Maximal number of sides in.
- `#define MAX_NB_EDGES 30000`
Maximal Number of edges.
- `#define MAX_NBDOF_NODE 6`
Maximum number of DOF supported by each node.
- `#define MAX_NBDOF_SIDE 6`
Maximum number of DOF supported by each side.
- `#define MAX_NBDOF_EDGE 2`
Maximum number of DOF supported by each edge.
- `#define MAX_NB_ELEMENT_NODES 20`
Maximum number of nodes by element.
- `#define MAX_NB_ELEMENT_EDGES 10`
Maximum number of edges by element.
- `#define MAX_NB_SIDE_NODES 9`
Maximum number of nodes by side.
- `#define MAX_NB_ELEMENT_SIDES 8`
Maximum number of sides by element.
- `#define MAX_NB_ELEMENT_DOF 27`
Maximum number of dof by element.
- `#define MAX_NB_SIDE_DOF 4`
Maximum number of dof by side.
- `#define MAX_NB_INT_PTS 20`
Maximum number of integration points in element.
- `#define MAX_NB_VERTICES 2000`
Maximum number of vertices.
- `#define MAX_NB_HOLES 10`
Maximum number of holes.
- `#define MAX_NB_LINES 200`
Maximum number of lines.
- `#define MAX_NB_LINE_NODES 1000`
Maximum number of nodes on each line.
- `#define MAX_NB_CONT_LINES 50`
Maximum number of lines on each contour.
- `#define MAX_NB_SUB_DOMAINS 5`
Maximum number of subdomains.
- `#define MAX_NB_MATERIALS 10`
Maximum number of materials.
- `#define TheNode (*theNode)`

- #define **TheElement** (*theElement)
- #define **TheSide** (*theSide)
- #define **TheEdge** (*theEdge)
- #define **MeshElements**(mesh) for ((mesh).topElement(); (theElement=(mesh).getElement());)
- #define **MeshActiveElements**(mesh) for ((mesh).topElement(); (theElement=(mesh).getActiveElement());)
- #define **MeshNodeLoop**(mesh, node) for ((mesh).topNode(); ((node)=(mesh).getNode());)
- #define **MeshNodes**(mesh) for ((mesh).topNode(); (theNode=(mesh).getNode());)
- #define **MeshBoundaryNodes**(mesh) for ((mesh).topBoundaryNode(); (theNode=(mesh).getBoundaryNode());)
- #define **MeshSides**(mesh) for ((mesh).topSide(); (theSide=(mesh).getSide());)
- #define **MeshSideSet**(sl) for ((sl).top(); (theSide=(sl).get());)
- #define **MeshBoundarySides**(mesh) for ((mesh).topBoundarySide(); (theSide=(mesh).getBoundarySide());)
- #define **MeshEdges**(mesh) for ((mesh).topEdge(); (theEdge=(mesh).getEdge());)
- #define **theNodeLabel** theNode->n()
- #define **theSideLabel** theSide->n()
- *A macro that returns side label in a loop using macro **MeshSides***
- #define **theSideNodeLabel**(i) theSide->getNodeLabel(i)
- *A macro that returns label of i-th node of side using macro **MeshSides***
- #define **theElementLabel** theElement->n()
- *A macro that returns element label in a loop using macro **MeshElements***
- #define **theElementNodeLabel**(i) theElement->getNodeLabel(i)
- *A macro that returns label of i-th node of element using macro **MeshElements***

Functions

- ostream & **operator<<** (ostream &s, const Edge &ed)
- *Output edge data.*
- ostream & **operator<<** (ostream &s, const Element &el)
- *Output element data.*
- Figure **operator&&** (const Figure &f1, const Figure &f2)
- *Function to define a **Figure** instance as the intersection of two **Figure** instances.*
- Figure **operator-** (const Figure &f1, const Figure &f2)
- *Function to define a **Figure** instance as the set subtraction of two **Figure** instances.*
- ostream & **operator<<** (ostream &s, const Material &m)
- *Output material data.*
- ostream & **operator<<** (ostream &s, const Mesh &ms)
- *Output mesh data.*
- ostream & **operator<<** (ostream &s, const MeshAdapt &a)
- *Output **MeshAdapt** class data.*
- ostream & **operator<<** (ostream &s, const NodeList &nl)
- *Output **NodeList** instance.*
- ostream & **operator<<** (ostream &s, const ElementList &el)
- *Output **ElementList** instance.*
- ostream & **operator<<** (ostream &s, const SideList &sl)
- *Output **SideList** instance.*
- ostream & **operator<<** (ostream &s, const EdgeList &el)

- Output *EdgeList* instance.

 - `size_t Label` (const Node &nd)
Return label of a given node.
 - `size_t Label` (const Element &el)
Return label of a given element.
 - `size_t Label` (const Side &sd)
Return label of a given side.
 - `size_t Label` (const Edge &ed)
Return label of a given edge.
 - `size_t NodeLabel` (const Element &el, size_t n)
Return global label of node local label in element.
 - `size_t NodeLabel` (const Side &sd, size_t n)
Return global label of node local label in side.
 - `Point< real_t > Coord` (const Node &nd)
Return coordinates of a given node.
 - `int Code` (const Node &nd, size_t i=1)
Return code of a given (degree of freedom of) node.
 - `int Code` (const Element &el)
Return code of a given element.
 - `int Code` (const Side &sd, size_t i=1)
Return code of a given (degree of freedom of) side.
 - `bool operator==` (const Element &el1, const Element &el2)
Check equality between 2 elements.
 - `bool operator==` (const Side &sd1, const Side &sd2)
Check equality between 2 sides.
 - `void DeformMesh` (Mesh &mesh, const Vect< real_t > &u, real_t a=1)
Calculate deformed mesh using a displacement field.
 - `void DeformMesh` (Mesh &mesh, const PETScVect< real_t > &u, real_t a=1)
Calculate deformed mesh using a displacement field as instance of *PETScVect*.
 - `void MeshToMesh` (Mesh &m1, Mesh &m2, const Vect< real_t > &u1, Vect< real_t > &u2, size_t nx, size_t ny=0, size_t nz=0, size_t dof=1)
Function to redefine a vector defined on a mesh to a new mesh.
 - `void MeshToMesh` (Mesh &m1, Mesh &m2, const Vect< real_t > &u1, Vect< real_t > &u2, const Point< real_t > &xmin, const Point< real_t > &xmax, size_t nx, size_t ny, size_t nz, size_t dof=1)
Function to redefine a vector defined on a mesh to a new mesh.
 - `real_t getMaxSize` (const Mesh &m)
Return maximal size of element edges for given mesh.
 - `real_t getMinSize` (const Mesh &m)
Return minimal size of element edges for given mesh.
 - `real_t getMinElementMeasure` (const Mesh &m)
Return minimal measure (length, area or volume) of elements of given mesh.
 - `real_t getMinSideMeasure` (const Mesh &m)
Return minimal measure (length or area) of sides of given mesh.
 - `real_t getMaxSideMeasure` (const Mesh &m)
Return maximal measure (length or area) of sides of given mesh.
 - `real_t getMeanElementMeasure` (const Mesh &m)

Return average measure (length, area or volume) of elements of given mesh.

- `real_t getMeanSideMeasure` (const Mesh &m)

Return average measure (length or area) of sides of given mesh.

- void `setNodeCodes` (Mesh &m, const string &exp, int code, size_t dof=1)

Assign a given code to all nodes satisfying a boolean expression using node coordinates.

- void `setBoundaryNodeCodes` (Mesh &m, const string &exp, int code, size_t dof=1)

Assign a given code to all nodes on boundary that satisfy a boolean expression using node coordinates.

- void `setSideCodes` (Mesh &m, const string &exp, int code, size_t dof=1)

Assign a given code to all sides satisfying a boolean expression using node coordinates.

- void `setBoundarySideCodes` (Mesh &m, const string &exp, int code, size_t dof=1)

Assign a given code to all sides on boundary that satisfy a boolean expression using node coordinates.

- void `setElementCodes` (Mesh &m, const string &exp, int code)

Assign a given code to all elements satisfying a boolean expression using node coordinates.

- int `NodeInElement` (const Node *nd, const Element *el)

Say if a given node belongs to a given element.

- int `NodeInSide` (const Node *nd, const Side *sd)

Say if a given node belongs to a given side.

- int `SideInElement` (const Side *sd, const Element *el)

Say if a given side belongs to a given element.

- ostream & `operator<<` (ostream &s, const Node &nd)

Output node data.

- ostream & `operator<<` (ostream &s, const Side &sd)

Output side data.

5.14.1 Detailed Description

Gathers mesh related classes.

5.14.2 Macro Definition Documentation

#define GRAPH_MEMORY 1000000

Memory necessary to store matrix graph.

This value is necessary only if nodes are to be renumbered.

#define MAX_NB_HOLES 10

Maximum number of holes.

Used only if class Domain is invoked

#define MAX_NB_LINES 200

Maximum number of lines.

Used only if class Domain is invoked

#define MAX_NB_LINE_NODES 1000

Maximum number of nodes on each line.

Used only if class Domain is invoked

#define MAX_NB_CONT_LINES 50

Maximum number of lines on each contour.

Used only if class Domain is invoked

#define MAX_NB_SUB_DOMAINS 5

Maximum number of subdomains.

Used only if class Domain is invoked

#define TheNode (*theNode)

A macro that gives the instance pointed by *theNode*

#define TheElement (*theElement)

A macro that gives the instance pointed by *theElement*

#define TheSide (*theSide)

A macro that gives the instance pointed by *theSide*

#define TheEdge (*theEdge)

A macro that gives the instance pointed by *theEdge*

#define MeshElements(mesh) for ((mesh).topElement(); (theElement)=(mesh).getElement());

A macro to loop on mesh elements *mesh*: Instance of Mesh

Note

: Each iteration updates the pointer *theElement* to current Element

#define MeshActiveElements(mesh) for ((mesh).topElement(); (theElement)=(mesh).getActiveElement());

A macro to loop on mesh active elements *mesh*: Instance of Mesh

Note

: Each iteration updates the pointer *theElement* to current Element

: This macro is necessary only if adaptive meshing is used

#define MeshNodeLoop(mesh, node) for ((mesh).topNode(); ((node)=(mesh).getNode());

A macro to loop on mesh nodes *mesh*: Instance of Mesh node: Pointer to pointed node

#define MeshNodes(mesh) for ((mesh).topNode(); (theNode)=(mesh).getNode());

A macro to loop on mesh nodes *mesh*: Instance of Mesh

Note

: Each iteration updates the pointer *theNode* to current Node


```
#define MeshBoundaryNodes( mesh ) for ((mesh).topBoundaryNode();  
(theNode=(mesh).getBoundaryNode());)
```

A macro to loop on mesh nodes `mesh`: Instance of `Mesh`

Note

: Each iteration updates the pointer `theNode` to current Node

```
#define MeshSides( mesh ) for ((mesh).topSide(); (theSide=(mesh).getSide());)
```

A macro to loop on mesh sides `mesh`: Instance of `Mesh`

Note

: Each iteration updates the pointer `theSide` to current Side

```
#define MeshSideSet( sl ) for ((sl).top(); (theSide=(sl).get());)
```

A macro to loop on a subset of mesh sides `sl`: Instance of `SideList` class

Note

: Each iteration updates the pointer `theSide` to current Side

```
#define MeshBoundarySides( mesh ) for ((mesh).topBoundarySide();  
(theSide=(mesh).getBoundarySide());)
```

A macro to loop on mesh boundary sides `mesh`: Instance of `Mesh`

Notes:

- List of boundary sides must have been previously created by using class `SideList`
- Each iteration updates the pointer `theSide` to current Side

```
#define MeshEdges( mesh ) for ((mesh).topEdge(); (theEdge=(mesh).getEdge());)
```

A macro to loop on mesh edges `mesh`: Instance of `Mesh`

Note

: Each iteration updates the pointer `theEdge` to current Edge

```
#define theNodeLabel theNode->n()
```

A macro that returns node label in a loop using macro `MeshNodes`

5.14.3 Function Documentation

Figure operator&& (const Figure & *f1*, const Figure & *f2*)

Function to define a [Figure](#) instance as the intersection of two [Figure](#) instances.

Function to define a [Figure](#) instance as the union of two [Figure](#) instances.

Parameters

in	<i>f1</i>	First Figure instance
in	<i>f2</i>	Second Figure instance

Returns

Updated resulting [Figure](#) instance

Figure operator- (const [Figure](#) & *f1*, const [Figure](#) & *f2*)

Function to define a [Figure](#) instance as the set subtraction of two [Figure](#) instances.

Parameters

in	<i>f1</i>	First Figure instance to subtract from
in	<i>f2</i>	Second Figure instance to subtract

Returns

Updated resulting [Figure](#) instance

size_t Label (const [Node](#) & *nd*)

Return label of a given node.

Parameters

in	<i>nd</i>	Reference to Node instance
----	-----------	--

Returns

Label of node

size_t Label (const [Element](#) & *el*)

Return label of a given element.

Parameters

in	<i>el</i>	Reference to Element instance
----	-----------	---

Returns

Label of element

size_t Label (const [Side](#) & *sd*)

Return label of a given side.

Parameters

in	<i>sd</i>	Reference to Side instance
----	-----------	--

Returns

Label of side

size_t Label (const [Edge](#) & *ed*)

Return label of a given edge.

Parameters

<code>in</code>	<code>ed</code>	Reference to Edge instance
-----------------	-----------------	--

Returns

Label of edge

size.t NodeLabel (const Element & *el*, size.t *n*)

Return global label of node local label in element.

Parameters

<code>in</code>	<code>el</code>	Reference to Element instance
<code>in</code>	<code>n</code>	Local label of node in element

Returns

Global label of node

size.t NodeLabel (const Side & *sd*, size.t *n*)

Return global label of node local label in side.

Parameters

<code>in</code>	<code>sd</code>	Reference to Side instance
<code>in</code>	<code>n</code>	Local label of node in side

Returns

Global label of node

Point< real.t > Coord (const Node & *nd*)

Return coordinates of a given node.

Parameters

<code>in</code>	<code>nd</code>	Reference to Node instance
-----------------	-----------------	--

Returns

Coordinates of node

int Code (const Node & *nd*, size.t *i* = 1)

Return code of a given (degree of freedom of) node.

Parameters

<code>in</code>	<code>nd</code>	Reference to Node instance
-----------------	-----------------	--

in	<i>i</i>	Label of dof [Default: 1]
-----------	----------	---------------------------

Returns

Code of dof of node

int Code (const Element & *el*)

Return code of a given element.

Parameters

in	<i>el</i>	Reference to Element instance
-----------	-----------	---

Returns

Code of element

int Code (const Side & *sd*, size_t *i* = 1)

Return code of a given (degree of freedom of) side.

Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>i</i>	Label of dof [Default: 1]

Returns

Code of dof of side

operator== (const Element & *el1*, const Element & *el2*)

Check equality between 2 elements.

Parameters

in	<i>el1</i>	Reference to first Side instance
in	<i>el2</i>	Reference to second Side instance

Returns

true is elements are equal, *i.e.* if they have the same nodes, false if not.

bool operator== (const Side & *sd1*, const Side & *sd2*)

Check equality between 2 sides.

Parameters

in	<i>sd1</i>	Reference to first Side instance
in	<i>sd2</i>	Reference to second Side instance

Returns

true is sides are equal, *i.e.* if they have the same nodes, false if not.

void DeformMesh (Mesh & *mesh*, const Vect< real.t > & *u*, real.t *a* = 1)

Calculate deformed mesh using a displacement field.

Parameters

in,out	<i>mesh</i>	Mesh instance. On output, node coordinates are modified to take into account the displacement
in	<i>u</i>	Displacement field at nodes
in	<i>a</i>	Amplification factor [Default: 1]. The displacement is multiplied by <i>a</i> before to be added to node coordinates

void DeformMesh (Mesh & *mesh*, const PETScVect< real.t > & *u*, real.t *a* = 1)

Calculate deformed mesh using a displacement field as instance of [PETScVect](#).

Parameters

in,out	<i>mesh</i>	Mesh instance. On output, node coordinates are modified to take into account the displacement
in	<i>u</i>	Displacement field at nodes
in	<i>a</i>	Amplification factor [Default: 1]. The displacement is multiplied by <i>a</i> before to be added to node coordinates

void MeshToMesh (Mesh & *m1*, Mesh & *m2*, const Vect< real.t > & *u1*, Vect< real.t > & *u2*, size.t *nx*, size.t *ny* = 0, size.t *nz* = 0, size.t *dof* = 1)

Function to redefine a vector defined on a mesh to a new mesh.

The program interpolates (piecewise linear) first the vector on a finer structured grid. Then the values on the new mesh nodes are computed.

Remarks

For efficiency the number of grid cells must be large enough so that interpolation provides efficient accuracy

Parameters

in	<i>m1</i>	Reference to the first mesh instance
out	<i>m2</i>	Reference to the second mesh instance
in	<i>u1</i>	Input vector of nodal values defined on first mesh
out	<i>u2</i>	Output vector of nodal values defined on second mesh
in	<i>nx</i>	Number of cells in the x-direction in the fine structured grid
in	<i>ny</i>	Number of cells in the y-direction in the fine structured grid The default value of <i>ny</i> is 0, i.e. a 1-D grid
in	<i>nz</i>	Number of cells in the z-direction in the fine structured grid The default value of <i>nz</i> is 0, i.e. a 1-D or 2-D grid
in	<i>dof</i>	Label of degree of freedom of vector <i>u</i> . Only this dof is considered. [Default: 1]

Note

The input vector *u1* is a one degree of freedom per node vector, i.e. its size must be equal (or greater than) the total number of nodes of mesh *m1*. The size of vector *u2* is deduced from the mesh *m2*

```
void MeshToMesh ( Mesh & m1, Mesh & m2, const Vect< real.t > & u1, Vect< real.t > & u2, const Point< real.t > & xmin, const Point< real.t > & xmax, size.t nx, size.t ny, size.t nz, size.t dof = 1 )
```

Function to redefine a vector defined on a mesh to a new mesh.

The program interpolates (piecewise linear) first the vector on a finer structured grid. Then the values on the new mesh nodes are computed. In this function the grid rectangle is defined so that this one can cover only a submesh of m1.

Remarks

For efficiency the number of grid cells must be large enough so that interpolation provides efficient accuracy

Parameters

in	<i>m1</i>	Reference to the first mesh instance
out	<i>m2</i>	Reference to the second mesh instance
in	<i>u1</i>	Input vector of nodal values defined on first mesh
out	<i>u2</i>	Output vector of nodal values defined on second mesh
in	<i>xmin</i>	Point instance containing minimal coordinates of the rectangle that defines the grid
in	<i>xmax</i>	Point instance containing maximal coordinates of the rectangle that defines the grid
in	<i>nx</i>	Number of cells in the x-direction in the fine structured grid
in	<i>ny</i>	Number of cells in the y-direction in the fine structured grid The default value of ny is 0, i.e. a 1-D grid
in	<i>nz</i>	Number of cells in the z-direction in the fine structured grid The default value of nz is 0, i.e. a 1-D or 2-D grid
in	<i>dof</i>	Label of degree of freedom of vector u. Only this dof is considered. [Default: 1]

Note

The input vector u1 is a one degree of freedom per node vector, i.e. its size must be equal (or greater than) the total number of nodes of mesh m1. The size of vector u2 is deduced from the mesh m2

```
real.t getMaxSize ( const Mesh & m )
```

Return maximal size of element edges for given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
----	----------	----------------------------

```
real.t getMinSize ( const Mesh & m )
```

Return minimal size of element edges for given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
----	----------	----------------------------

```
real.t getMinElementMeasure ( const Mesh & m )
```

Return minimal measure (length, area or volume) of elements of given mesh.

Return maximal measure (length, area or volume) of elements of given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
-----------	----------	----------------------------

real.t getMinSideMeasure (const Mesh & *m*)

Return minimal measure (length or area) of sides of given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
-----------	----------	----------------------------

Note

Use this function only if sides are present in the mesh and for 2-D meshes

real.t getMaxSideMeasure (const Mesh & *m*)

Return maximal measure (length or area) of sides of given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
-----------	----------	----------------------------

Note

Use this function only if sides are present in the mesh and for 2-D meshes

real.t getMeanElementMeasure (const Mesh & *m*)

Return average measure (length, area or volume) of elements of given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
-----------	----------	----------------------------

real.t getMeanSideMeasure (const Mesh & *m*)

Return average measure (length or area) of sides of given mesh.

Parameters

in	<i>m</i>	Reference to mesh instance
-----------	----------	----------------------------

Note

Use this function only if sides are present in the mesh and for 2-D meshes

void setNodeCodes (Mesh & *m*, const string & *exp*, int *code*, size.t *dof* = 1)

Assign a given code to all nodes satisfying a boolean expression using node coordinates.

Parameters

in	<i>m</i>	Reference to mesh instance
in	<i>exp</i>	Regular expression using x, y, and z coordinates of nodes, according to <code>fparser</code> parser
in	<i>code</i>	Code to assign
in	<i>dof</i>	Degree of freedom for which code is assigned [Default: 1]

void setBoundaryNodeCodes (Mesh & *m*, const string & *exp*, int *code*, size_t *dof* = 1)

Assign a given code to all nodes on boundary that satisfy a boolean expression using node coordinates.

Parameters

in	<i>m</i>	Reference to mesh instance
in	<i>exp</i>	Regular expression using x, y, and z coordinates of nodes, according to <code>fparser</code> parser
in	<i>code</i>	Code to assign
in	<i>dof</i>	Degree of freedom for which code is assigned [Default: 1]

void setSideCodes (Mesh & *m*, const string & *exp*, int *code*, size_t *dof* = 1)

Assign a given code to all sides satisfying a boolean expression using node coordinates.

Parameters

in	<i>m</i>	Reference to mesh instance
in	<i>exp</i>	Regular expression using x, y, and z coordinates of side nodes, according to <code>fparser</code> parser
in	<i>code</i>	Code to assign
in	<i>dof</i>	Degree of freedom for which code is assigned [Default: 1]

void setBoundarySideCodes (Mesh & *m*, const string & *exp*, int *code*, size_t *dof* = 1)

Assign a given code to all sides on boundary that satisfy a boolean expression using node coordinates.

Parameters

in	<i>m</i>	Reference to mesh instance
in	<i>exp</i>	Regular expression using x, y, and z coordinates of side nodes, according to <code>fparser</code> parser
in	<i>code</i>	Code to assign
in	<i>dof</i>	Degree of freedom for which code is assigned [Default: 1]

void setElementCodes (Mesh & *m*, const string & *exp*, int *code*)

Assign a given code to all elements satisfying a boolean expression using node coordinates.

Parameters

in	<i>m</i>	Reference to mesh instance
in	<i>exp</i>	Regular expression using x, y, and z coordinates of element nodes, according to <code>fparser</code> parser
in	<i>code</i>	Code to assign

int NodeInElement (const Node * *nd*, const Element * *el*)

Say if a given node belongs to a given element.

Parameters

in	<i>nd</i>	Pointer to Node
in	<i>el</i>	Pointer to Element

Returns

Local label of the node if this one is found, 0 if not.

int NodeInside (const Node * *nd*, const Side * *sd*)

Say if a given node belongs to a given side.

Parameters

in	<i>nd</i>	Pointer to Node
in	<i>sd</i>	Pointer to Side

Returns

Local label of the node if this one is found, 0 if not.

int SideInElement (const Side * *sd*, const Element * *el*)

Say if a given side belongs to a given element.

Parameters

in	<i>sd</i>	Pointer to Side
in	<i>el</i>	Pointer to Element

Returns

Local label of the side if this one is found, 0 if not.

5.15 Shape Function

Gathers shape function classes.

Classes

- class [FEShape](#)
Parent class from which inherit all finite element shape classes.
- class [triangle](#)
Defines a triangle. The reference element is the rectangle triangle with two unit edges.
- class [Hexa8](#)
Defines a three-dimensional 8-node hexahedral finite element using Q_1 -isoparametric interpolation.
- class [Line2](#)
To describe a 2-Node planar line finite element.
- class [Line2H](#)
To describe a 2-Node Hermite planar line finite element.
- class [Line3](#)
To describe a 3-Node quadratic planar line finite element.
- class [Penta6](#)
Defines a 6-node pentahedral finite element using P_1 interpolation in local coordinates $(s.x, s.y)$ and Q_1 isoparametric interpolation in local coordinates $(s.x, s.z)$ and $(s.y, s.z)$.
- class [Quad4](#)
Defines a 4-node quadrilateral finite element using Q_1 isoparametric interpolation.
- class [Tetra4](#)
Defines a three-dimensional 4-node tetrahedral finite element using P_1 interpolation.
- class [Triang3](#)
Defines a 3-Node (P_1) triangle.
- class [Triang6S](#)
Defines a 6-Node straight triangular finite element using P_2 interpolation.

5.15.1 Detailed Description

Gathers shape function classes.

5.16 Solver

Gathers Solver functions.

Files

- file [OptimAux.h](#)
File that contains auxiliary functions for optimization.
- file [OptimSA.h](#)
Function to solve an optimization problem using the Simulated Annealing method.
- file [OptimTN.h](#)
Function to solve an optimization problem using the Truncated Newton method.

Classes

- class [Reconstruction](#)
To perform various reconstruction operations.
- class [EigenProblemSolver](#)
Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, i.e. Find scalars l and non-null vectors v such that $[K]\{v\} = l[M]\{v\}$ where $[K]$ and $[M]$ are symmetric matrices. The eigenproblem can be originated from a PDE. For this, we will refer to the matrices K and M as Stiffness and Mass matrices respectively.
- class [Iter< T_ >](#)
Class to drive an iterative process.
- class [ODESolver](#)
To solve a system of ordinary differential equations.
- class [Prec< T_ >](#)
To set a preconditioner.
- class [TimeStepping](#)
To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$.

Macros

- `#define MAX_NB_EQUATIONS 5`
Maximum number of equations.
- `#define MAX_NB_INPUT_FIELDS 3`
Maximum number of fields for an equation.
- `#define MAX_NB_MESHES 10`
Maximum number of meshes.
- `#define TIME_LOOP(ts, t, ft, n)`
A macro to loop on time steps to integrate on time ts : Time step t : Initial time value updated at each time step ft : Final time value n : Time step index.
- `#define TimeLoop`
A macro to loop on time steps to integrate on time.
- `#define IterationLoop while (++theIteration<MaxNbIterations && Converged==false)`
A macro to loop on iterations for an iterative procedure.

Functions

- `ostream & operator<< (ostream &s, const Muscl3DT &m)`
Output mesh data as calculated in class [Muscl3DT](#).
- `template<class T_ >`
`int BiCG (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Biconjugate gradient solver function.
- `template<class T_ >`
`int BiCGStab (const SpMatrix< T_ > &A, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Biconjugate gradient stabilized solver function.
- `template<class T_ >`
`int BiCGStab (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Biconjugate gradient stabilized solver function.
- `template<class T_ >`
`int CG (const SpMatrix< T_ > &A, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Conjugate gradient solver function.
- `template<class T_ >`
`int CG (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Conjugate gradient solver function.
- `template<class T_ >`
`int CGS (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
Conjugate Gradient Squared solver function.
- `template<class T_ >`
`int GMRes (const SpMatrix< T_ > &A, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_ > &x, size_t m, int max_it, real_t toler, int verbose)`
GMRes solver function.
- `template<class T_ >`
`int GMRes (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, size_t m, int max_it, real_t toler, int verbose)`
GMRes solver function.
- `template<class T_ >`
`int GS (const SpMatrix< T_ > &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int max_it, real_t toler, int verbose)`
Gauss-Seidel solver function.
- `template<class T_ >`
`int Jacobi (const SpMatrix< T_ > &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int max_it, real_t toler, int verbose)`
Jacobi solver function.
- `void BCAsConstraint (const Mesh &m, const Vect< real_t > &bc, Vect< real_t > &up, Vect< real_t > &low)`
*To impose Dirichlet boundary conditions in an optimization problem. If such conditions are to present, this function has to be invoked by giving on input `bc(i)` as the value to impose for the *i*-th optimization variable.*

- `template<class OPT_>`
`int OptimSA (OPT_ &theOpt, Vect< real_t > &x, real_t &rt, real_t &eps, int &ns, int &nt, int &neps, int &maxevl, Vect< real_t > &lb, Vect< real_t > &ub, Vect< real_t > &c, int &msg_lvl, int &seed1, int &seed2, real_t &t, Vect< real_t > &vm, Vect< real_t > &xopt, real_t &fopt, int &nacc, int &nfcnev, int &nobds)`
Simulated annealing optimization solver.
- `template<class OPT_>`
`int OptimTN (OPT_ &theOpt, Vect< real_t > &x, Vect< real_t > &low, Vect< real_t > &up, Vect< int > &pivot, int max_it, real_t toler, int msg_lvl)`
Truncated Newton optimization solver.
- `template<class T_ , class M_>`
`int Richardson (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int max_it, real_t toler, int verbose)`
Richardson solver function.
- `template<class T_>`
`void Schur (SkMatrix< T_ > &A, SpMatrix< T_ > &U, SpMatrix< T_ > &L, SpMatrix< T_ > &D, Vect< T_ > &b, Vect< T_ > &c)`
Solve a linear system of equations with a 2x2-block matrix.
- `template<class T_>`
`void Schur (PETScMatrix< T_ > &A, PETScMatrix< T_ > &U, PETScMatrix< T_ > &L, PETScMatrix< T_ > &D, PETScVect< T_ > &b, PETScVect< T_ > &c)`
Solve a linear system of equations with a 2x2-block matrix.
- `template<class T_ , class M_>`
`int SSOR (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`
SSOR solver function.
- `ostream & operator<< (ostream &s, const TimeStepping &ts)`
Output differential system information.

5.16.1 Detailed Description

Gathers Solver functions.

5.16.2 Macro Definition Documentation

#define MAX_NB_EQUATIONS 5

Maximum number of equations.

Useful for coupled problems

#define MAX_NB_INPUT_FIELDS 3

Maximum number of fields for an equation.

Useful for coupled problems

#define MAX_NB_MESHES 10

Maximum number of meshes.

Useful for coupled problems

#define TimeLoop**Value:**

```
NbTimeSteps = int(theFinalTime/theTimeStep); \
    for (theTime=theTimeStep, theStep=1; theTime<
        theFinalTime+0.001*theTimeStep; theTime+=
            theTimeStep, ++theStep)
```

A macro to loop on time steps to integrate on time.

It uses the following global variables defined in **OFELI**: theStep, theTime, theTimeStep, theFinalTime

#define IterationLoop while (++theIteration<MaxNbIterations && Converged==false)

A macro to loop on iterations for an iterative procedure.

It uses the following global variables defined in **OFELI**: theIteration, MaxNbIterations, Converged

5.16.3 Function Documentation

int BiCG (const SpMatrix< T_ > & A, int prec, const Vect< T_ > & b, Vect< T_ > & x, int max_it, real_t toler, int verbose)

Biconjugate gradient solver function.

Parameters

in	<i>A</i>	Problem matrix (Instance of class SpMatrix).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDE-NT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class Vect)
in,out	<i>x</i>	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	<i>max_it</i>	Maximum number of iterations.
	<i>toler</i>	[in] Tolerance for convergence (measured in relative weighted 2--Norm).
	<i>verbose</i>	[in] Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

<T_>	Data type (double, float, complex<double>, ...)
------	---

int BiCGStab (const SpMatrix< T_ > & A, const Prec< T_ > & P, const Vect< T_ > & b, Vect< T_ > & x, int max_it, real_t toler, int verbose)

Biconjugate gradient stabilized solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	P	Preconditioner (Instance of class Prec).
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess on input and solution of the linear system on output (If iterations have succeeded).
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

$\langle T_ \rangle$	Data type (double, float, complex<double>, ...)
-----------------------	---

int BiCGStab (const [SpMatrix](#)< T_ > & A, int *prec*, const [Vect](#)< T_ > & b, [Vect](#)< T_ > & x, int *max_it*, real.t *toler*, int *verbose*)

Biconjugate gradient stabilized solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	$prec$	Enum variable selecting a preconditioner, among the values IDENT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

<code><T_></code>	Data type (double, float, complex<double>, ...)
-------------------------	---

```
int CG ( const SpMatrix< T_ > & A, const Prec< T_ > & P, const Vect< T_ > & b, Vect< T_ > & x, int max_it, real_t toler, int verbose )
```

Conjugate gradient solver function.

Parameters

<code>in</code>	<code>A</code>	Problem matrix (Instance of class SpMatrix).
<code>in</code>	<code>P</code>	Preconditioner (Instance of class Prec).
<code>in</code>	<code>b</code>	Right-hand side vector (class Vect)
<code>in,out</code>	<code>x</code>	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
<code>in</code>	<code>max_it</code>	Maximum number of iterations.
<code>in</code>	<code>toler</code>	Tolerance for convergence (measured in relative weighted 2--Norm).
<code>in</code>	<code>verbose</code>	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

<code><T_></code>	Data type (double, float, complex<double>, ...)
-------------------------	---

```
int CG ( const SpMatrix< T_ > & A, int prec, const Vect< T_ > & b, Vect< T_ > & x, int max_it, real_t toler, int verbose )
```

Conjugate gradient solver function.

Parameters

<code>in</code>	<code>A</code>	Problem matrix (Instance of abstract class SpMatrix).
<code>in</code>	<code>prec</code>	Enum variable selecting a preconditioner, among the values IDE-NT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
<code>in</code>	<code>b</code>	Right-hand side vector (class Vect)
<code>in,out</code>	<code>x</code>	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
<code>in</code>	<code>max_it</code>	Maximum number of iterations.
<code>in</code>	<code>toler</code>	Tolerance for convergence (measured in relative weighted 2--Norm).

in	<i>verbose</i>	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.
-----------	----------------	--

Returns

Number of performed iterations,

Template Parameters

$\langle T_ \rangle$	Data type (double, float, complex<double>, ...)
-----------------------	---

int CGS (const SpMatrix< T_ > & A, int prec, const Vect< T_ > & b, Vect< T_ > & x, int max_it, real_t toler, int verbose)

Conjugate Gradient Squared solver function.

Parameters

in	<i>A</i>	Problem matrix (Instance of class SpMatrix).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDE-NT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class Vect)
in,out	<i>x</i>	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	<i>max_it</i>	Maximum number of iterations.
in	<i>toler</i>	Tolerance for convergence (measured in relative weighted 2--Norm).
in	<i>verbose</i>	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information, • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations

Template Parameters

$\langle T_ \rangle$	Data type (real_t, float, complex<real_t>, ...)
-----------------------	---

int GMRes (const SpMatrix< T_ > & A, const Prec< T_ > & P, const Vect< T_ > & b, Vect< T_ > & x, size_t m, int max_it, real_t toler, int verbose)

GMRes solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	P	Preconditioner (Instance of class Prec).
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	m	Number of subspaces to generate for iterations.
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter (0: No output, 1: Output iteration information, 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

$\langle T_ \rangle$	Data type (double, float, complex<double>, ...)
-----------------------	---

int GMRes (const [SpMatrix](#)< $T_$ > & A , int $prec$, const [Vect](#)< $T_$ > & b , [Vect](#)< $T_$ > & x , size.t m , int max_it , real.t $toler$, int $verbose$)

GMRes solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	$prec$	Enum variable selecting a preconditioner, among the values IDE-NT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	m	Number of subspaces to generate for iterations.
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter (0: No output, 1: Output iteration information, 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

$\langle T_ \rangle$	Data type (double, float, complex<double>, ...)
-----------------------	---

int GS (const [SpMatrix](#)< $T_$ > & A , const [Vect](#)< $T_$ > & b , [Vect](#)< $T_$ > & x , real.t ω , int max_it , real.t $toler$, int $verbose$)

Gauss-Seidel solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	ω	Relaxation parameter.
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter <ul style="list-style-type: none"> • 0: No output • 1: Output iteration information • 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations

Template Parameters

$\langle T_ \rangle$	Data type (real.t, float, complex<real.t>, ...)
-----------------------	---

int Jacobi (const [SpMatrix](#)< T_ > & A, const [Vect](#)< T_ > & b, [Vect](#)< T_ > & x, real.t ω , int max_it , real.t $toler$, int $verbose$)

Jacobi solver function.

Parameters

in	A	Problem matrix (Instance of class SpMatrix).
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	ω	Relaxation parameter.
in	max_it	Maximum number of iterations.
in,out	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter (0: No output, 1: Output iteration information, 2 and greater: Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Parameters

$\langle T_ \rangle$	Data type (real.t, float, complex<real.t>, ...)
$\langle M_ \rangle$	Matrix storage class

```
int void BCAsConstraint ( const Mesh & m, const Vect< real.t > & bc, Vect< real.t > & up,  
Vect< real.t > & low )
```

To impose Dirichlet boundary conditions in an optimization problem. If such conditions are to present, this function has to be invoked by giving on input `bc(i)` as the value to impose for the *i*-th optimization variable.

Parameters

in	<i>m</i>	Mesh instance
in	<i>bc</i>	Vect instance where <code>bc(i)</code> is the value to impose for dof <i>i</i>
out	<i>up</i>	Vect instance that contains on output upper bounds for DOFs
out	<i>low</i>	Vect instance that contains on output lower bounds for DOFs

```
int OptimSA ( OPT_ & theOpt, Vect< real.t > & x, real.t & rt, real.t & eps, int & ns, int &  
nt, int & neps, int & maxevl, Vect< real.t > & lb, Vect< real.t > & ub, Vect< real.t > & c,  
int & msg.lvl, int & seed1, int & seed2, real.t & t, Vect< real.t > & vm, Vect< real.t > &  
xopt, real.t & fopt, int & nacc, int & nfcnev, int & nobds )
```

Simulated annealing optimization solver.

Simulated annealing is a global optimization method that distinguishes between different local optima. Starting from an initial point, the algorithm takes a step and the function is evaluated. When minimizing a function, any downhill step is accepted and the process repeats from this new point. An uphill step may be accepted. Thus, it can escape from local optima. This uphill decision is made by the Metropolis criteria. As the optimization process proceeds, the length of the stx decline and the algorithm closes in on the global optimum. Since the algorithm makes very few assumptions regarding the function to be optimized, it is quite robust with respect to non-quadratic surfaces. The degree of robustness can be adjusted by the user. In fact, simulated annealing can be used as a local optimizer for difficult functions.

This implementation of simulated annealing was used in "Global Optimization of Statistical Functions with Simulated Annealing," Goffe, Ferrier and Rogers, Journal of Econometrics, vol. 60, no. 1/2, Jan./Feb. 1994, pp. 65-100. Briefly, we found it competitive, if not superior, to multiple restarts of conventional optimization routines for difficult optimization problems.

For more information on this routine, contact its author: Bill Goffe, bgoffe@whale.st.usm.edu

Synopsis: This function implements the continuous simulated annealing global optimization algorithm described in Corana et al.'s article "Minimizing Multimodal Functions of Continuous Variables with the "Simulated Annealing" Algorithm" in the September 1987 (vol. 13, no. 3, pp. 262-280) issue of the ACM Transactions on Mathematical Software.

A very quick (perhaps too quick) overview of OptimSA:

OptimSA tries to find the global optimum of an *N* dimensional function. It moves both up and downhill and as the optimization process proceeds, it focuses on the most promising area.

To start, it randomly chooses a trial point within the step length *vm* of the user selected starting point. The function is evaluated at this trial point and its value is compared to its value at the initial point.

In a maximization problem, all uphill moves are accepted and the algorithm continues from that trial point. Downhill moves may be accepted; the decision is made by the Metropolis criteria. It uses *T* (temperature) and the size of the downhill move in a probabilistic manner. The smaller *t* and the size of the downhill move are, the more likely that move will be accepted. If the trial is accepted, the algorithm moves on from that point. If it is rejected, another point is chosen instead for a trial evaluation.

Each element of *vm* periodically adjusted so that half of all function evaluations in that direction are accepted.

A fall in *t* is imposed upon the system with the *rt* variable by $t(i+1) = rt*t(i)$ where *i* is the *i*-th iteration. Thus, as *t* declines, downhill moves are less likely to be accepted and the percentage

of rejections rise. Given the scheme for the selection for vm , vm falls. Thus, as t declines, vm falls and OptimSA focuses upon the most promising area for optimization.

The importance of the parameter t :

The parameter t is crucial in using OptimSA successfully. It influences vm , the step length over which the algorithm searches for optima. For a small initial t , the step length may be too small; thus not enough of the function might be evaluated to find the global optima. The user should carefully examine vm in the intermediate output (set `msg_lvl = 1`) to make sure that vm is appropriate. The relationship between the initial temperature and the resulting step length is function dependent.

To determine the starting temperature that is consistent with optimizing a function, it is worthwhile to run a trial run first. Set $rt = 1.5$ and $t = 1.0$. With $rt > 1.0$, the temperature increases and vm rises as well. Then select the T that produces a large enough vm .

For modifications to the algorithm and many details on its use, (particularly for econometric applications) see Goffe, Ferrier and Rogers, "Global Optimization of Statistical Functions with Simulated Annealing," Journal of Econometrics, vol. 60, no. 1/2, Jan./Feb. 1994, pp. 65-100.

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As far as possible, the parameters here have the same name as in the description of the algorithm on pp. 266-8 of Corana et al.

Note: The suggested values generally come from Corana et al. To drastically reduce runtime, see Goffe et al., pp. 90-1 for suggestions on choosing the appropriate rt and nt .

Parameters

in	<i>theOpt</i>	Instance of class <i>OPT_</i> that is implemented by the user and that provides the objective function.
in	x	The starting values for the variables of the function to be optimized.
in	rt	The temperature reduction factor. The value suggested by Corana et al. is .85. See Goffe et al. for more advice.
in	eps	Error tolerance for termination. If the final function values from the last nepts temperatures differ from the corresponding value at the current temperature by less than eps and the final function value at the current temperature differs from the current optimal function value by less than eps , execution terminates and the value 0 is returned.
in	ns	Number of cycles. After $ns*n$ function evaluations, each element of vm is adjusted so that approximately half of all function evaluations are accepted. The suggested value is 20.
in	nt	Number of iterations before temperature reduction. After $nt*ns*n$ function evaluations, temperature (t) is changed by the factor rt . Value suggested by Corana et al. is $\max(100, 5*n)$. See Goffe et al. for further advice.

in	<i>neps</i>	Number of final function values used to decide upon termination. See <i>eps</i> . Suggested value is 4
	<i>maxevl</i>	[in] The maximum number of function evaluations. If it is exceeded, the return <i>code</i> =1.
in	<i>lb</i>	The lower bound for the allowable solution variables.
in	<i>ub</i>	The upper bound for the allowable solution variables. If the algorithm chooses $x(i) < lb(i)$ or $x(i) > ub(i)$ $i=1,...,n$, a point is from inside is randomly selected. This focuses the algorithm on the region inside <i>ub</i> and <i>lb</i> . Unless the user wishes to concentrate the search to a particular region, <i>ub</i> and <i>lb</i> should be set to very large positive and negative values, respectively. Note that the starting vector <i>x</i> should be inside this region. Also note that <i>lb</i> and <i>ub</i> are fixed in position, while <i>vm</i> is centered on the last accepted trial set of variables that optimizes the function.
	<i>c</i>	[in] Vector that controls the step length adjustment. The suggested value for all elements is 2.
in	<i>msg_lvl</i>	controls printing inside <i>OptimSA</i> . <ul style="list-style-type: none"> • 0 - Nothing printed. • 1 - Function value for the starting value and summary results before each temperature reduction. This includes the optimal function value found so far, the total number of moves (broken up into uphill, downhill, accepted and rejected), the number of out of bounds trials, the number of new optima found at this temperature, the current optimal <i>x</i> and the step length <i>vm</i>. Note that there are $n*ns*nt$ function evaluations before each temperature reduction. Finally, notice is also given upon achieving the termination criteria. • 2 - Each new step length (<i>vm</i>), the current optimal <i>x</i> (<i>xopt</i>) and the current trial <i>x</i> (<i>x</i>). This gives the user some idea about how far <i>x</i> strays from <i>xopt</i> as well as how <i>vm</i> is adapting to the function. • 3 - Each function evaluation, its acceptance or rejection and new optima. For many problems, this option will likely require a small tree if hard copy is used. This option is best used to learn about the algorithm. A small value for <i>MAXEVL</i> is thus recommended when using <i>msg_lvl</i>=3. Suggested value: 1 <p>Note: For a given value of <i>msg_lvl</i>, the lower valued options (other than 0) are utilized.</p>
in	<i>seed1</i>	The first seed for the random number generator <i>ranmar</i> .. $0 \leq seed1 \leq 31328$. (integer)
in	<i>seed2</i>	The second seed for the random number generator <i>ranmar</i> .. $0 \leq seed \leq 30081$. Different values for <i>seed1</i> and <i>seed2</i> will lead to an entirely different sequence of trial points and decisions on downhill moves (when maximizing). See Goffe et al. on how this can be used to test the results of <i>OptimSA</i> .
in	<i>t</i>	On input, the initial temperature. See Goffe et al. for advice. On output, the final temperature.
in	<i>vm</i>	The step length vector. On input it should encompass the region of interest given the starting value <i>x</i> . For point <i>x</i> [<i>i</i>], the next trial point is selected is from <i>x</i> [<i>i</i>]- <i>vm</i> [<i>i</i>] to <i>x</i> [<i>i</i>]+ <i>vm</i> [<i>i</i>]. Since <i>vm</i> is adjusted so that about half of all points are accepted, the input value is not very important (i.e. is the value is off, <i>OptimSA</i> adjusts <i>vm</i> to the correct value).
OFELI's Reference Guide		
out	<i>xopt</i>	The variables that optimize the function.
out	<i>fopt</i>	The optimal value of the function.
out	<i>nacc</i>	The number of accepted function evaluations.
out	<i>nfcnev</i>	The total number of function evaluations. In a minor point, note

Returns

- 0 - Normal return; termination criteria achieved.
- 1 - Number of function evaluations (nfcnev) is greater than the maximum number (maxevl).
- 2 - The starting value (x) is not inside the bounds (lb and ub).
- 3 - The initial temperature is not positive.
- 99 - Should not be seen; only used internally.

Template Parameters

<code><OPT_></code>	Class that defined the objective function and its gradient
---------------------------	--

```
int OptimTN ( OPT_ & theOpt, Vect< real.t > & x, Vect< real.t > & low, Vect< real.t > &
up, Vect< int > & pivot, int max_it = - 1, real.t toler = 100*OFELI.EPSMCH, int msg_lvl = 5
)
```

Truncated Newton optimization solver.

Solves a bounds-constrained optimization problem using the Nash's Truncated Newton Algorithm (See paper by S.G. Nash, Newton-type Minimization via the Lanczos method, SIAM J. Numer. Anal. 21 (1984) 770-778). All vector variables are instances of class [Vect<real.t>](#).

Parameters

in	<i>theOpt</i>	Instance of class OPT_ that is implemented by the user and that provides the objective function.
in,out	<i>x</i>	Vector that contains an initial guess of the solution and as output the final optimization variables if optimization has succeeded
in	<i>low</i>	Vector of the same size as x that contains for each variable the lower bound to impose. Note that Dirichlet boundary conditions are treated as equality conditions (i.e. lower and upper bounds) and that these ones can be imposed via an auxiliary optimization file (BCAsConstraint)
in	<i>up</i>	Vector of the same size as x that contains for each variable the upper bound to impose. Note that Dirichlet boundary conditions are treated as equality conditions (i.e. lower and upper bounds) and that these ones can be imposed via an auxiliary optimization function BCAsConstraint)
in	<i>pivot</i>	Vector of the same size as x that contains on return for each variable an integer value that says if the corresponding constraint was reached (different from 0) or not (= 0). Note that Dirichlet boundary conditions are treated as equality constraints
in	<i>max_it</i>	Maximum number of iterations for convergence
in	<i>toler</i>	Tolerance for convergence (measured in relative weighted 2--Norm of projected gradient)
in	<i>msg_lvl</i>	Output message level. Must be between 0 and 10

Returns

Number of performed iterations

Template Parameters

<code><OPT_></code>	Class that provides the objective function. This class is defined by the user.
---------------------------	--

The **OPT_** class:

This class is defined by the user. It must have the member function :

void Objective(Vect<real_t> &x, real_t &f, Vect<real_t> &g)

Here above, *x* is the optimization variable vector, *f* is the value of the objective to calculate for the given *x* and *g* is the gradient vector for *x*.

The function **BCAsConstraint**:

This function is defined by the user:

void BCAsConstraint(const Mesh &m, const Vect<real_t> &bc, Vect<real_t> &up, Vect<real_t> &low)

This function imposes Dirichlet boundary conditions in an optimization problem as optimization constraints. If such conditions are to be present, this function has to be invoked by giving on input *bc(i)* as the value to impose for the *i*-th optimization variable.

int Richardson (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int max_it, real_t toler, int verbose)

Richardson solver function.

Parameters

in	<i>A</i>	Problem matrix problem (Instance of abstract class M_).
in	<i>b</i>	Right-hand side vector (class Vect)
	<i>x</i>	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	<i>omega</i>	Relaxation parameter.
in	<i>max_it</i>	Maximum number of iterations.
in	<i>toler</i>	Tolerance for convergence (measured in relative weighted 2--Norm).
in	<i>verbose</i>	Information output parameter (0: No output, 1: Output iteration information, 2 and greater: Output iteration information and solution at each iteration.

Returns

nb_it Number of performed iterations,

Template Parameters

<code><T_></code>	Data type (real_t, float, complex<real_t>, ...)
<code><M_></code>	Matrix storage class

void Schur (SkMatrix< T_ > &A, SpMatrix< T_ > &U, SpMatrix< T_ > &L, SpMatrix< T_ > &D, Vect< T_ > &b, Vect< T_ > &c)

Solve a linear system of equations with a 2x2-block matrix.

The linear system is of the form

$$\begin{bmatrix} A & U \\ L & D \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} b \\ c \end{bmatrix}$$

Parameters

in	A	Instance of class SkMatrix class for the first diagonal block. The matrix must be invertible and factorizable (Do not use SpMatrix class) where A, U, L, D are instances of matrix classes,
in	U	Instance of class SpMatrix for the upper triangle block. The matrix can be rectangular
in	L	Instance of class SpMatrix for the lower triangle block. The matrix can be rectangular
in	D	Instance of class SpMatrix for the second diagonal block. The matrix must be factorizable (Do not use SpMatrix class)
in,out	b	Vector (Instance of class Vect) that contains the first block of right-hand side on input and the first block of the solution on output. b must have the same size as the dimension of A .
in,out	c	Vect instance that contains the second block of right-hand side on output and the first block of the solution on output. c must have the same size as the dimension of D .

Template Argument:

Template Parameters

$\langle T_ \rangle$	data type (real_t, float, ...)
-----------------------	--------------------------------

void Schur (PETScMatrix< T_ > & A, PETScMatrix< T_ > & U, PETScMatrix< T_ > & L, PETScMatrix< T_ > & D, PETScVect< T_ > & b, PETScVect< T_ > & c)

Solve a linear system of equations with a 2x2-block matrix.

The linear system is of the form

$$\begin{bmatrix} A & U \\ L & D \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix} = \begin{bmatrix} b \\ c \end{bmatrix}$$

Parameters

in	A	Instance of class SkMatrix class for the first diagonal block. The matrix must be invertible and factorizable (Do not use SpMatrix class) where A, U, L, D are instances of matrix classes,
in	U	Instance of class PETScMatrix for the upper triangle block. The matrix can be rectangular
in	L	Instance of class PETScMatrix for the lower triangle block. The matrix can be rectangular
in	D	Instance of class PETScMatrix for the second diagonal block. The matrix must be factorizable (Do not use SpMatrix class)
in,out	b	Vector (Instance of class PETScVect) that contains the first block of right-hand side on input and the first block of the solution on output. b must have the same size as the dimension of A .
in,out	c	PETScVect instance that contains the second block of right-hand side on output and the first block of the solution on output. c must have the same size as the dimension of D .

Template Argument:

Template Parameters

$\langle T_ \rangle$	data type (real_t, float, ...)
-----------------------	--------------------------------

int SSOR (const $M_$ & A , const Vect< $T_$ > & b , Vect< $T_$ > & x , int max_it , real_t $toler$, int $verbose$)

SSOR solver function.
Parameters

in	A	Problem matrix (Instance of abstract class $M_$).
in	b	Right-hand side vector (class Vect)
in,out	x	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	max_it	Maximum number of iterations.
in	$toler$	Tolerance for convergence (measured in relative weighted 2--Norm).
in	$verbose$	Information output parameter (0: No output, 1: Output iteration information, 2 and greater : Output iteration information and solution at each iteration.

Returns

Number of performed iterations,

Template Arguments:

- $T_$ data type (double, float, ...)
- $M_$ Matrix storage class

5.17 OFELI

Namespaces

- [OFELI](#)

A namespace to group all library classes, functions, ...

5.17.1 Detailed Description

Chapter 6

Namespace Documentation

6.1 OFELI Namespace Reference

A namespace to group all library classes, functions, ...

Classes

- class [SkMatrix](#)
To handle square matrices in skyline storage format.
- class [SkSMatrix](#)
To handle symmetric matrices in skyline storage format.
- class [SpMatrix](#)
To handle matrices in sparse storage format.
- class [AbsEqua](#)
Mother abstract class to describe equation.
- class [LocalVect](#)
Handles small size vectors like element vectors.
- class [ICPG1D](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D.
- class [ICPG2DT](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D.
- class [ICPG3DT](#)
Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D.
- class [LCL1D](#)
Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.
- class [LCL2DT](#)
Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.
- class [LCL3DT](#)
Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.
- class [Muscl](#)
Parent class for hyperbolic solvers with Muscl scheme.
- class [Vect](#)
To handle general purpose vectors.
- class [Muscl1D](#)
Class for 1-D hyperbolic solvers with [Muscl](#) scheme.

- class [Muscl2DT](#)
Class for 2-D hyperbolic solvers with [Muscl](#) scheme.
- class [Muscl3DT](#)
Class for 3-D hyperbolic solvers with [Muscl](#) scheme using tetrahedra.
- class [BiotSavart](#)
Class to compute the magnetic induction from the current density using the Biot-Savart formula.
- class [EC2D1T3](#)
Eddy current problems in 2-D domains using solenoidal approximation.
- class [Equa.Electromagnetics](#)
Abstract class for Electromagnetics [Equation](#) classes.
- class [HelmholtzBT3](#)
Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.
- class [Equation](#)
Abstract class for all equation classes.
- class [Equa.Fluid](#)
Abstract class for Fluid Dynamics [Equation](#) classes.
- class [NSP2DQ41](#)
Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using Q_1/P_0 element and a penalty formulation for the incompressibility condition.
- class [TINS2DT3B](#)
Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.
- class [FastMarching2D](#)
To run a Fast Marching Method on 2-D structured uniform grids.
- class [FMM2D](#)
class for the fast marching 2-D algorithm
- class [FMM3D](#)
class for the 3-D fast marching algorithm
- class [FMMSolver](#)
The Fast Marching Method solver.
- class [Equa.Laplace](#)
Abstract class for classes about the Laplace equation.
- class [Laplace1DL2](#)
To build element equation for a 1-D elliptic equation using the 2-Node line element (P_1).
- class [Laplace1DL3](#)
To build element equation for the 1-D elliptic equation using the 3-Node line (P_2).
- class [Laplace2DFVT](#)
To build and solve the Laplace equation using a standard Finite Volume method.
- class [Laplace2DMHRT0](#)
To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas RT_0).
- class [Laplace2DT3](#)
To build element equation for the Laplace equation using the 2-D triangle element (P_1).
- class [SteklovPoincare2DBE](#)
Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.
- class [Bar2DL2](#)
To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node.
- class [Beam3DL2](#)

- To build element equations for 3-D beam equations using 2-node lines.*

 - class [Elas2DQ4](#)
- To build element equations for 2-D linearized elasticity using 4-node quadrilaterals.*

 - class [Elas2DT3](#)
- To build element equations for 2-D linearized elasticity using 3-node triangles.*

 - class [Elas3DH8](#)
- To build element equations for 3-D linearized elasticity using 8-node hexahedra.*

 - class [Elas3DT4](#)
- To build element equations for 3-D linearized elasticity using 4-node tetrahedra.*

 - class [Equa_Solid](#)
- Abstract class for Solid Mechanics Finite Element classes.*

 - class [DC1DL2](#)
- Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements.*

 - class [DC2DT3](#)
- Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.*

 - class [DC2DT6](#)
- Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles.*

 - class [DC3DAT3](#)
- Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles.*

 - class [DC3DT4](#)
- Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra.*

 - class [Equa_Therm](#)
- Abstract class for Heat transfer Finite Element classes.*

 - class [PhaseChange](#)
- This class enables defining phase change laws for a given material.*

 - class [Funct](#)
- A simple class to parse real valued functions.*

 - class [IOField](#)
- Enables working with files in the XML Format.*

 - class [IPF](#)
- To read project parameters from a file in [IPF](#) format.*

 - class [Prescription](#)
- To prescribe various types of data by an algebraic expression. Data may consist in boundary conditions, forces, tractions, fluxes, initial condition. All these data types can be defined through an enumerated variable.*

 - class [Tabulation](#)
- To read and manipulate tabulated functions.*

 - class [UserData](#)
- Abstract class to define by user various problem data.*

 - class [BMatrix](#)
- To handle band matrices.*

 - class [DMatrix](#)
- To handle dense matrices.*

 - class [DSMatrix](#)
- To handle symmetric dense matrices.*

 - class [LocalMatrix](#)

- Handles small size matrices like element matrices, with a priori known size.*
- class [Matrix](#)
 - Virtual class to handle matrices for all storage formats.*
- class [PETScVect](#)
 - To handle general purpose vectors using Petsc.*
- class [PETScMatrix](#)
 - To handle matrices in sparse storage format using the Petsc library.*
- class [PETScWrapper](#)
 - This class is a wrapper to be used when the library Petsc is installed and used with [OFELI](#).*
- class [Point](#)
 - Defines a point with arbitrary type coordinates.*
- class [Point2D](#)
 - Defines a 2-D point with arbitrary type coordinates.*
- class [Prec](#)
 - To set a preconditioner.*
- class [TrMatrix](#)
 - To handle tridiagonal matrices.*
- class [Domain](#)
 - To store and treat finite element geometric information.*
- class [Edge](#)
 - To describe an edge.*
- class [Element](#)
 - To store and treat finite element geometric information.*
- class [Figure](#)
 - To store and treat a figure (or shape) information.*
- class [Rectangle](#)
 - To store and treat a rectangular figure.*
- class [Brick](#)
 - To store and treat a brick (parallelepiped) figure.*
- class [Circle](#)
 - To store and treat a circular figure.*
- class [Sphere](#)
 - To store and treat a sphere.*
- class [Ellipse](#)
 - To store and treat an ellipsoidal figure.*
- class [Triangle](#)
 - To store and treat a triangle.*
- class [Polygon](#)
 - To store and treat a polygonal figure.*
- class [Grid](#)
 - To manipulate structured grids.*
- class [Material](#)
 - To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members.*
- class [Mesh](#)
 - To store and manipulate finite element meshes.*
- class [MeshAdapt](#)

- To adapt mesh in function of given solution.*

 - class [NodeList](#)

Class to construct a list of nodes having some common properties.
- class [ElementList](#)

Class to construct a list of elements having some common properties.
- class [SideList](#)

Class to construct a list of sides having some common properties.
- class [EdgeList](#)

Class to construct a list of edges having some common properties.
- class [Node](#)

To describe a node.
- class [Partition](#)

To partition a finite element mesh into balanced submeshes.
- class [Side](#)

To store and treat finite element sides (edges in 2-D or faces in 3-D)
- class [Estimator](#)

To calculate an a posteriori estimator of the solution.
- class [Reconstruction](#)

To perform various reconstruction operations.
- class [FEShape](#)

Parent class from which inherit all finite element shape classes.
- class [triangle](#)

Defines a triangle. The reference element is the rectangle triangle with two unit edges.
- class [Hexa8](#)

Defines a three-dimensional 8-node hexahedral finite element using Q_1 -isoparametric interpolation.
- class [Line2](#)

To describe a 2-Node planar line finite element.
- class [Line2H](#)

To describe a 2-Node Hermite planar line finite element.
- class [Line3](#)

To describe a 3-Node quadratic planar line finite element.
- class [Penta6](#)

Defines a 6-node pentahedral finite element using P_1 interpolation in local coordinates $(s.x, s.y)$ and Q_1 isoparametric interpolation in local coordinates $(s.x, s.z)$ and $(s.y, s.z)$.
- class [Quad4](#)

Defines a 4-node quadrilateral finite element using Q_1 isoparametric interpolation.
- class [Tetra4](#)

Defines a three-dimensional 4-node tetrahedral finite element using P_1 interpolation.
- class [Triang3](#)

Defines a 3-Node (P_1) triangle.
- class [Triang6S](#)

Defines a 6-Node straight triangular finite element using P_2 interpolation.
- class [EigenProblemSolver](#)

Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, i.e. Find scalars λ and non-null vectors v such that $[K]\{v\} = \lambda[M]\{v\}$ where $[K]$ and $[M]$ are symmetric matrices. The eigenproblem can be originated from a PDE. For this, we will refer to the matrices K and M as Stiffness and Mass matrices respectively.

- class [Iter](#)

Class to drive an iterative process.

- class [ODESolver](#)

To solve a system of ordinary differential equations.

- class [TimeStepping](#)

To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$.

- class [Gauss](#)

Calculate data for Gauss integration.

- class [Timer](#)

To handle elapsed time counting.

Enumerations

- enum [PDE_Terms](#) {
[MASS](#) = 0,
[CONSISTENT_MASS](#) = 0,
[LUMPED_MASS](#) = 0x00001000,
[CAPACITY](#) = 0x00002000,
[CONSISTENT_CAPACITY](#) = 0x00002000,
[LUMPED_CAPACITY](#) = 0x00004000,
[VISCOSITY](#) = 0x00008000,
[STIFFNESS](#) = 0x00010000,
[DIFFUSION](#) = 0x00020000,
[CONVECTION](#) = 0x00040000,
[DEVIATORIC](#) = 0x00080000,
[DILATATION](#) = 0x00100000,
[ELECTRIC](#) = 0x00200000,
[MAGNETIC](#) = 0x00400000,
[LOAD](#) = 0x00800000,
[HEAT_SOURCE](#) = 0x01000000,
[BOUNDARY_TRACTION](#) = 0x02000000,
[HEAT_FLUX](#) = 0x04000000,
[CONTACT](#) = 0x08000000,
[BUOYANCY](#) = 0x10000000,
[LORENTZ_FORCE](#) = 0x20000000 }
- enum [EqDataType](#) {

- ```

INITIAL_FIELD = 1,
SOLUTION = 1,
INITIAL_AUX_1 = 2,
INITIAL_AUX_2 = 3,
INITIAL_AUX_3 = 4,
INITIAL_AUX_4 = 5,
BOUNDARY_CONDITION = 6,
BODY_FORCE = 7,
SOURCE = 7,
POINT_FORCE = 8,
BOUNDARY_FORCE = 9,
FLUX = 9,
TRACTION = 9,
AUX_INPUT_FIELD_1 = 10,
AUX_INPUT_FIELD_2 = 11,
AUX_INPUT_FIELD_3 = 12,
AUX_INPUT_FIELD_4 = 13,
DISPLACEMENT_FIELD = 14,
VELOCITY_FIELD = 15,
TEMPERATURE_FIELD = 16 }

```
- enum `ArrayType` {  
`LOCAL_ARRAY` = 0,  
`GLOBAL_ARRAY` = 1 }
  - enum `TimeScheme` {  
`STATIONARY` = 0,  
`FORWARD_EULER` = 1,  
`BACKWARD_EULER` = 2,  
`CRANK_NICOLSON` = 3,  
`HEUN` = 4,  
`NEWMARK` = 5,  
`LEAP_FROG` = 6,  
`ADAMS_BASHFORTH` = 7,  
`AB2` = 7,  
`RUNGE_KUTTA` = 8,  
`RK4` = 8,  
`RK3_TVD` = 9,  
`BDF2` = 10 }
  - enum `PDE` {  
`LAPLACE`,  
`DIFFUSION_CONVECTION`,  
`THERMAL_PHASE_CHANGE`,  
`INCOMPRESSIBLE_NAVIER_STOKES`,  
`LINEARIZED_ELASTICITY`,  
`PLANAR_TRUSS`,  
`SPATIAL_BEAM` }
  - enum `FEType` {  
`FE_2D_3N`,  
`FE_2D_6N`,  
`FE_2D_4N`,  
`FE_3D_AXI_3N`,  
`FE_3D_4N`,  
`FE_3D_8N` }
  - enum `AnalysisType` {

- STEADY\_STATE,  
TRANSIENT,  
OPTIMIZATION }
- enum `MatrixType` {  
SKYLINE = 0x00800000,  
SPARSE = 0x01000000,  
DIAGONAL = 0x02000000,  
TRIDIAGONAL = 0x04000000,  
SYMMETRIC = 0x08000000,  
UNSYMMETRIC = 0x10000000,  
IDENTITY = 0x12000000 }
- enum `Iteration` {  
DIRECT\_SOLVER = 0,  
CG\_SOLVER = 1,  
CGS\_SOLVER = 2,  
BICG\_SOLVER = 3,  
BICG\_STAB\_SOLVER = 4,  
GMRES\_SOLVER = 5 }
- Choose iterative solver for the linear system.*
- enum `Preconditioner` {  
IDENT\_PREC = 0,  
DIAG\_PREC = 1,  
DILU\_PREC = 2,  
ILU\_PREC = 3,  
SSOR\_PREC = 4 }
- Choose preconditioner for the linear system.*
- enum `BCType` {  
PERIODIC\_A = 9999,  
PERIODIC\_B = -9999,  
CONTACT\_BC = 9998 ,  
SLIP = 9996 }

## Functions

- `ostream & operator<<` (`ostream &s`, const `Muscl3DT` &m)  
*Output mesh data as calculated in class `Muscl3DT`.*
- `T_ * A` ()  
*Return element matrix.*
- `T_ * b` ()  
*Return element right-hand side.*
- `T_ * Prev` ()  
*Return element previous vector.*
- `ostream & operator<<` (`ostream &s`, const `complex.t` &x)  
*Output a complex number.*
- `ostream & operator<<` (`ostream &s`, const `std::string` &c)  
*Output a string.*
- `template<class T_ >`  
`ostream & operator<<` (`ostream &s`, const `vector< T_ >` &v)  
*Output a vector instance.*
- `template<class T_ >`  
`ostream & operator<<` (`ostream &s`, const `std::pair< T_, T_ >` &a)

*Output a pair instance.*

- void `saveField` (`Vect< real_t > &v`, string `output_file`, int `opt`)  
*Save a vector to an output file in a given file format.*
- void `saveField` (`PETScVect< real_t > &v`, string `output_file`, int `opt`)  
*Save a PETSc vector to an output file in a given file format.*
- void `saveField` (`PETScVect< real_t > &v`, const `Mesh &mesh`, string `output_file`, int `opt`)  
*Save a PETSc vector to an output file in a given file format.*
- void `saveField` (`Vect< real_t > &v`, const `Grid &g`, string `output_file`, int `opt`)  
*Save a vector to an output file in a given file format, for a structured grid data.*
- void `saveGnuplot` (string `input_file`, string `output_file`, string `mesh_file`)  
*Save a vector to an input Gnuplot file.*
- void `saveTecplot` (string `input_file`, string `output_file`, string `mesh_file`)  
*Save a vector to an output file to an input Tecplot file.*
- void `saveVTK` (string `input_file`, string `output_file`, string `mesh_file`)  
*Save a vector to an output VTK file.*
- void `saveGmsh` (string `input_file`, string `output_file`, string `mesh_file`)  
*Save a vector to an output Gmsh file.*
- ostream & `operator<<` (ostream &`s`, const `Tabulation &t`)  
*Output Tabulated function data.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalVect< T_, N_ > &be`, `Vect< T_ > &b`)  
*Assemble local vector into global vector.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `Vect< T_ > &b`)  
*Assemble diagonal local vector into global vector.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `Matrix< T_ > *A`)  
*Assemble local matrix into global matrix.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `SkMatrix< T_ > &A`)  
*Assemble local matrix into global skyline matrix.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `SkSMatrix< T_ > &A`)  
*Assemble local matrix into global symmetric skyline matrix.*
- template<class `T_`, size\_t `N_`, class `E_` >  
void `element_assembly` (const `E_ &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `SpMatrix< T_ > &A`)  
*Assemble local matrix into global sparse matrix.*
- template<class `T_`, size\_t `N_` >  
void `side_assembly` (const `Element &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `SpMatrix< T_ > &A`)  
*Side assembly of local matrix into global matrix (as instance of class SpMatrix).*
- template<class `T_`, size\_t `N_` >  
void `side_assembly` (const `Element &e`, const `LocalMatrix< T_, N_, N_ > &ae`, `SkSMatrix< T_ > &A`)

*Side assembly of local matrix into global matrix (as instance of class [SkMatrix](#)).*

- `template<class T_, size_t N_>`  
`void side\_assembly (const Element &e, const LocalMatrix< T_, N_, N_ > &ae, SkMatrix< T_ > &A)`

*Side assembly of local matrix into global matrix (as instance of class [SkMatrix](#)).*

- `template<class T_, size_t N_>`  
`void side\_assembly (const Element &e, const LocalVect< T_, N_ > &be, Vect< T_ > &b)`

*Side assembly of local vector into global vector.*

- `template<class T_ >`  
`BMatrix< T_ > operator\* (T_ a, const BMatrix< T_ > &a)`

*Operator \* (Premultiplication of matrix by constant)*

- `template<class T_ >`  
`ostream & operator<< (ostream &s, const BMatrix< T_ > &a)`

*Output matrix in output stream.*

- `template<class T_ >`  
`ostream & operator<< (ostream &s, const DMatrix< T_ > &a)`

*Output matrix in output stream.*

- `template<class T_ >`  
`ostream & operator<< (ostream &s, const DSMatrix< T_ > &a)`

*Output matrix in output stream.*

- `template<class T_, size_t NR_, size_t NC_>`  
`LocalMatrix< T_, NR_, NC_ > operator\* (T_ a, const LocalMatrix< T_, NR_, NC_ > &x)`

*Operator \* (Multiply matrix x by scalar a)*

- `template<class T_, size_t NR_, size_t NC_>`  
`LocalMatrix< T_, NR_, NC_ > operator/ (T_ a, const LocalMatrix< T_, NR_, NC_ > &x)`

*Operator / (Divide matrix x by scalar a)*

- `template<class T_, size_t NR_, size_t NC_>`  
`LocalMatrix< T_, NR_, NC_ > operator+ (const LocalMatrix< T_, NR_, NC_ > &x, const LocalMatrix< T_, NR_, NC_ > &y)`

*Operator + (Add matrix x to y)*

- `template<class T_, size_t NR_, size_t NC_>`  
`LocalMatrix< T_, NR_, NC_ > operator- (const LocalMatrix< T_, NR_, NC_ > &x, const LocalMatrix< T_, NR_, NC_ > &y)`

*Operator - (Subtract matrix y from x)*

- `template<class T_, size_t NR_, size_t NC_>`  
`ostream & operator<< (ostream &s, const LocalMatrix< T_, NR_, NC_ > &a)`

*Output vector in output stream.*

- `template<class T_, size_t N_>`  
`LocalVect< T_, N_ > operator+ (const LocalVect< T_, N_ > &x, const LocalVect< T_, N_ > &y)`

*Operator + (Add two vectors)*

- `template<class T_, size_t N_>`  
`LocalVect< T_, N_ > operator- (const LocalVect< T_, N_ > &x, const LocalVect< T_, N_ > &y)`

*Operator - (Subtract two vectors)*

- `template<class T_, size_t N_>`  
`LocalVect< T_, N_ > operator\* (T_ a, const LocalVect< T_, N_ > &x)`

*Operator \* (Premultiplication of vector by constant)*

- `template<class T_, size_t N_>`  
`LocalVect< T_, N_ > operator/ (T_ a, const LocalVect< T_, N_ > &x)`  
*Operator / (Division of vector by constant)*
- `template<class T_, size_t N_>`  
`real_t Dot (const LocalVect< T_, N_ > &a, const LocalVect< T_, N_ > &b)`  
*Calculate dot product of 2 vectors (instances of class LocalVect)*
- `template<class T_, size_t N_>`  
`void Scale (T_ a, const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`  
*Multiply vector x by constant a and store result in y.*
- `template<class T_, size_t N_>`  
`void Scale (T_ a, LocalVect< T_, N_ > &x)`  
*Multiply vector x by constant a and store result in x.*
- `template<class T_, size_t N_>`  
`void Axy (T_ a, const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`  
*Add a\*x to vector y.*
- `template<class T_, size_t N_>`  
`void Copy (const LocalVect< T_, N_ > &x, LocalVect< T_, N_ > &y)`  
*Copy vector x into vector y.*
- `template<class T_, size_t N_>`  
`ostream & operator<< (ostream &s, const LocalVect< T_, N_ > &v)`  
*Output vector in output stream.*
- `template<class T_>`  
`PETScVect< T_ > operator* (const PETScMatrix< T_ > &A, const PETScVect< T_ > &x)`
- `template<class T_>`  
`ostream & operator<< (ostream &s, PETScMatrix< T_ > &A)`  
*Output matrix in output stream.*
- `string itos (int i)`  
*Function to convert an integer to a string.*
- `string dtos (real_t d)`  
*Function to convert a real to a string.*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const PETScWrapper< T_ > &w)`  
*Output Petsc Wrapper data in output stream.*
- `template<class T_>`  
`bool operator== (const Point< T_ > &a, const Point< T_ > &b)`  
*Operator ==*
- `template<class T_>`  
`Point< T_ > operator+ (const Point< T_ > &a, const Point< T_ > &b)`  
*Operator +*
- `template<class T_>`  
`Point< T_ > operator+ (const Point< T_ > &a, const T_ &x)`  
*Operator +*
- `template<class T_>`  
`Point< T_ > operator- (const Point< T_ > &a)`  
*Unary Operator -*
- `template<class T_>`  
`Point< T_ > operator- (const Point< T_ > &a, const Point< T_ > &b)`  
*Operator -*



- `template<class T_>`  
`Point< T_ > operator-` (const `Point< T_ > &a`, const `T_ &x`)  
*Operator -*
- `template<class T_>`  
`Point< T_ > operator*` (const `T_ &a`, const `Point< T_ > &b`)  
*Operator \**
- `template<class T_>`  
`Point< T_ > operator*` (const int `&a`, const `Point< T_ > &b`)  
*Operator \*.*
- `template<class T_>`  
`Point< T_ > operator*` (const `Point< T_ > &b`, const `T_ &a`)  
*Operator /*
- `template<class T_>`  
`Point< T_ > operator*` (const `Point< T_ > &b`, const int `&a`)  
*Operator \**
- `template<class T_>`  
`T_ operator*` (const `Point< T_ > &a`, const `Point< T_ > &b`)  
*Operator \**
- `template<class T_>`  
`Point< T_ > operator/` (const `Point< T_ > &b`, const `T_ &a`)  
*Operator /*
- `Point< double > CrossProduct` (const `Point< double > &lp`, const `Point< double > &rp`)  
*Return Cross product of two vectors `lp` and `rp`*
- `bool areClose` (const `Point< double > &a`, const `Point< double > &b`, double `toler=OFELI_TOLERANCE`)  
*Return `true` if both instances of class `Point<double>` are distant with less then `toler`*
- `double SqrDistance` (const `Point< double > &a`, const `Point< double > &b`)  
*Return squared euclidean distance between points `a` and `b`*
- `double Distance` (const `Point< double > &a`, const `Point< double > &b`)  
*Return euclidean distance between points `a` and `b`*
- `template<class T_>`  
`std::ostream & operator<<` (std::ostream `&s`, const `Point< T_ > &a`)  
*Output point coordinates.*
- `template<class T_>`  
`bool operator==` (const `Point2D< T_ > &a`, const `Point2D< T_ > &b`)  
*Operator ==.*
- `template<class T_>`  
`Point2D< T_ > operator+` (const `Point2D< T_ > &a`, const `Point2D< T_ > &b`)  
*Operator +.*
- `template<class T_>`  
`Point2D< T_ > operator+` (const `Point2D< T_ > &a`, const `T_ &x`)  
*Operator +.*
- `template<class T_>`  
`Point2D< T_ > operator-` (const `Point2D< T_ > &a`)  
*Unary Operator -*
- `template<class T_>`  
`Point2D< T_ > operator-` (const `Point2D< T_ > &a`, const `Point2D< T_ > &b`)  
*Operator -*

- `template<class T_>`  
`Point2D< T_> operator-` (const `Point2D< T_> &a`, const `T_ &x`)  
*Operator -*
- `template<class T_>`  
`Point2D< T_> operator*` (const `T_ &a`, const `Point2D< T_> &b`)  
*Operator \*.*
- `template<class T_>`  
`Point2D< T_> operator*` (const int `&a`, const `Point2D< T_> &b`)
- `template<class T_>`  
`Point2D< T_> operator*` (const `Point2D< T_> &b`, const `T_ &a`)  
*Operator /*
- `template<class T_>`  
`Point2D< T_> operator*` (const `Point2D< T_> &b`, const int `&a`)  
*Operator \**
- `template<class T_>`  
`T_ operator*` (const `Point2D< T_> &b`, const `Point2D< T_> &a`)  
*Operator \*.*
- `template<class T_>`  
`Point2D< T_> operator/` (const `Point2D< T_> &b`, const `T_ &a`)  
*Operator /*
- `bool areClose` (const `Point2D< real_t > &a`, const `Point2D< real_t > &b`, `real_t` `toler=OFELI.TOLERANCE`)  
*Return `true` if both instances of class `Point2D<real_t>` are distant with less then `toler` [Default: `OFELI.EPSMCH`].*
- `real_t SqrDistance` (const `Point2D< real_t > &a`, const `Point2D< real_t > &b`)  
*Return squared euclidean distance between points `a` and `b`*
- `real_t Distance` (const `Point2D< real_t > &a`, const `Point2D< real_t > &b`)  
*Return euclidean distance between points `a` and `b`*
- `template<class T_>`  
`std::ostream & operator<<` (std::ostream `&s`, const `Point2D< T_> &a`)  
*Output point coordinates.*
- `template<class T_>`  
`ostream & operator<<` (ostream `&s`, const `SkMatrix< T_> &a`)  
*Output matrix in output stream.*
- `template<class T_>`  
`ostream & operator<<` (ostream `&s`, const `SkSMatrix< T_> &a`)  
*Output matrix in output stream.*
- `template<class T_>`  
`ostream & operator<<` (ostream `&s`, const `SpMatrix< T_> &A`)
- `template<class T_>`  
`TrMatrix< T_> operator*` (`T_ a`, const `TrMatrix< T_> &A`)  
*Operator \* (Premultiplication of matrix by constant)*
- `template<class T_>`  
`ostream & operator<<` (ostream `&s`, const `TrMatrix< T_> &a`)  
*Output matrix in output stream.*
- `ostream & operator<<` (ostream `&s`, const `Edge &ed`)  
*Output edge data.*
- `ostream & operator<<` (ostream `&s`, const `Element &el`)  
*Output element data.*

- **Figure operator&&** (const **Figure** &f1, const **Figure** &f2)  
Function to define a **Figure** instance as the intersection of two **Figure** instances.
- **Figure operator-** (const **Figure** &f1, const **Figure** &f2)  
Function to define a **Figure** instance as the set subtraction of two **Figure** instances.
- void **getMesh** (string file, ExternalFileFormat form, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in an external file format.
- void **getBamg** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Bamg** format.
- void **getEasymesh** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Easymesh** format.
- void **getGambit** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Gambit** neutral format.
- void **getGmsh** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Gmsh** format.
- void **getMatlab** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a Matlab mesh data.
- void **getNetgen** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Netgen** format.
- void **getTetgen** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Tetgen** format.
- void **getTriangle** (string file, **Mesh** &mesh, size\_t nb\_dof=1)  
Construct an instance of class **Mesh** from a mesh file stored in **Triangle** format.
- ostream & **operator<<** (ostream &s, const **Grid** &g)  
Output grid data.
- ostream & **operator<<** (ostream &s, const **Material** &m)  
Output material data.
- ostream & **operator<<** (ostream &s, const **Mesh** &ms)  
Output mesh data.
- ostream & **operator<<** (ostream &s, const **MeshAdapt** &a)  
Output **MeshAdapt** class data.
- ostream & **operator<<** (ostream &s, const **NodeList** &nl)  
Output **NodeList** instance.
- ostream & **operator<<** (ostream &s, const **ElementList** &el)  
Output **ElementList** instance.
- ostream & **operator<<** (ostream &s, const **SideList** &sl)  
Output **SideList** instance.
- ostream & **operator<<** (ostream &s, const **EdgeList** &el)  
Output **EdgeList** instance.
- size\_t **Label** (const **Node** &nd)  
Return label of a given node.
- size\_t **Label** (const **Element** &el)  
Return label of a given element.
- size\_t **Label** (const **Side** &sd)  
Return label of a given side.
- size\_t **Label** (const **Edge** &ed)  
Return label of a given edge.

- `size_t NodeLabel (const Element &el, size_t n)`  
*Return global label of node local label in element.*
- `size_t NodeLabel (const Side &sd, size_t n)`  
*Return global label of node local label in side.*
- `Point< real_t > Coord (const Node &nd)`  
*Return coordinates of a given node.*
- `int Code (const Node &nd, size_t i=1)`  
*Return code of a given (degree of freedom of) node.*
- `int Code (const Element &el)`  
*Return code of a given element.*
- `int Code (const Side &sd, size_t i=1)`  
*Return code of a given (degree of freedom of) side.*
- `bool operator== (const Element &el1, const Element &el2)`  
*Check equality between 2 elements.*
- `bool operator== (const Side &sd1, const Side &sd2)`  
*Check equality between 2 sides.*
- `void DeformMesh (Mesh &mesh, const Vect< real_t > &u, real_t a=1)`  
*Calculate deformed mesh using a displacement field.*
- `void DeformMesh (Mesh &mesh, const PETScVect< real_t > &u, real_t a=1)`  
*Calculate deformed mesh using a displacement field as instance of PETScVect.*
- `void MeshToMesh (Mesh &m1, Mesh &m2, const Vect< real_t > &u1, Vect< real_t > &u2, size_t nx, size_t ny=0, size_t nz=0, size_t dof=1)`  
*Function to redefine a vector defined on a mesh to a new mesh.*
- `void MeshToMesh (Mesh &m1, Mesh &m2, const Vect< real_t > &u1, Vect< real_t > &u2, const Point< real_t > &xmin, const Point< real_t > &xmax, size_t nx, size_t ny, size_t nz, size_t dof=1)`  
*Function to redefine a vector defined on a mesh to a new mesh.*
- `real_t getMaxSize (const Mesh &m)`  
*Return maximal size of element edges for given mesh.*
- `real_t getMinSize (const Mesh &m)`  
*Return minimal size of element edges for given mesh.*
- `real_t getMinElementMeasure (const Mesh &m)`  
*Return minimal measure (length, area or volume) of elements of given mesh.*
- `real_t getMinSideMeasure (const Mesh &m)`  
*Return minimal measure (length or area) of sides of given mesh.*
- `real_t getMaxSideMeasure (const Mesh &m)`  
*Return maximal measure (length or area) of sides of given mesh.*
- `real_t getMeanElementMeasure (const Mesh &m)`  
*Return average measure (length, area or volume) of elements of given mesh.*
- `real_t getMeanSideMeasure (const Mesh &m)`  
*Return average measure (length or area) of sides of given mesh.*
- `void setNodeCodes (Mesh &m, const string &exp, int code, size_t dof=1)`  
*Assign a given code to all nodes satisfying a boolean expression using node coordinates.*
- `void setBoundaryNodeCodes (Mesh &m, const string &exp, int code, size_t dof=1)`  
*Assign a given code to all nodes on boundary that satisfy a boolean expression using node coordinates.*
- `void setSideCodes (Mesh &m, const string &exp, int code, size_t dof=1)`  
*Assign a given code to all sides satisfying a boolean expression using node coordinates.*

- void `setBoundarySideCodes` (`Mesh` &m, const string &exp, int code, size\_t dof=1)  
*Assign a given code to all sides on boundary that satisfy a boolean expression using node coordinates.*
- void `setElementCodes` (`Mesh` &m, const string &exp, int code)  
*Assign a given code to all elements satisfying a boolean expression using node coordinates.*
- int `NodeInElement` (const `Node` \*nd, const `Element` \*el)  
*Say if a given node belongs to a given element.*
- int `NodeInSide` (const `Node` \*nd, const `Side` \*sd)  
*Say if a given node belongs to a given side.*
- int `SideInElement` (const `Side` \*sd, const `Element` \*el)  
*Say if a given side belongs to a given element.*
- ostream & `operator<<` (ostream &s, const `Node` &nd)  
*Output node data.*
- void `saveMesh` (const string &file, const `Mesh` &mesh, ExternalFileFormat form)  
*This function saves mesh data a file for a given external format.*
- void `saveGmsh` (const string &gp\_file, const `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `Gmsh` format.*
- void `saveGnuplot` (const string &file, const `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `Gmsh` format.*
- void `saveMatlab` (const string &file, const `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `Matlab` format.*
- void `saveTecplot` (const string &file, const `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `Tecplot` format.*
- void `saveVTK` (const string &file, const `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `VTK` format.*
- void `saveBamg` (const string &file, `Mesh` &mesh)  
*This function outputs a `Mesh` instance in a file in `Bamg` format.*
- ostream & `operator<<` (ostream &s, const `Side` &sd)  
*Output side data.*
- ostream & `operator<<` (ostream &s, const `Estimator` &r)  
*Output estimator vector in output stream.*
- template<class T\_ >  
int `BiCG` (const `SpMatrix`< T\_ > &A, int prec, const `Vect`< T\_ > &b, `Vect`< T\_ > &x, int max\_it, `real_t` toler, int verbose)  
*Biconjugate gradient solver function.*
- template<class T\_ >  
int `BiCGStab` (const `SpMatrix`< T\_ > &A, const `Prec`< T\_ > &P, const `Vect`< T\_ > &b, `Vect`< T\_ > &x, int max\_it, `real_t` toler, int verbose)  
*Biconjugate gradient stabilized solver function.*
- template<class T\_ >  
int `BiCGStab` (const `SpMatrix`< T\_ > &A, int prec, const `Vect`< T\_ > &b, `Vect`< T\_ > &x, int max\_it, `real_t` toler, int verbose)  
*Biconjugate gradient stabilized solver function.*
- void `BSpline` (size\_t n, size\_t t, `Vect`< `Point`< `real_t` > > &control, `Vect`< `Point`< `real_t` > > &output, size\_t num\_output)  
*Function to perform a B-spline interpolation.*
- template<class T\_ >  
int `CG` (const `SpMatrix`< T\_ > &A, const `Prec`< T\_ > &P, const `Vect`< T\_ > &b, `Vect`< T\_ > &x, int max\_it, `real_t` toler, int verbose)

*Conjugate gradient solver function.*

- `template<class T_>`  
`int CG (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it,`  
`real_t toler, int verbose)`

*Conjugate gradient solver function.*

- `template<class T_>`  
`int CGS (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int`  
`max_it, real_t toler, int verbose)`

*Conjugate Gradient Squared solver function.*

- `template<class T_>`  
`int GMRes (const SpMatrix< T_ > &A, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_`  
`> &x, size_t m, int max_it, real_t toler, int verbose)`

*GMRes solver function.*

- `template<class T_>`  
`int GMRes (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, size_t`  
`m, int max_it, real_t toler, int verbose)`

*GMRes solver function.*

- `template<class T_>`  
`int GS (const SpMatrix< T_ > &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int`  
`max_it, real_t toler, int verbose)`

*Gauss-Seidel solver function.*

- `template<class T_>`  
`int Jacobi (const SpMatrix< T_ > &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega,`  
`int max_it, real_t toler, int verbose)`

*Jacobi solver function.*

- `void BCAsConstraint (const Mesh &m, const Vect< real_t > &bc, Vect< real_t > &up, Vect<`  
`real_t > &low)`

*To impose Dirichlet boundary conditions in an optimization problem. If such conditions are to present, this function has to be invoked by giving on input `bc(i)` as the value to impose for the *i*-th optimization variable.*

- `template<class OPT_>`  
`int OptimSA (OPT_ &theOpt, Vect< real_t > &x, real_t &rt, real_t &eps, int &ns, int &nt, int`  
`&neps, int &maxevl, Vect< real_t > &lb, Vect< real_t > &ub, Vect< real_t > &c, int &msg_l-`  
`lvl, int &seed1, int &seed2, real_t &t, Vect< real_t > &vm, Vect< real_t > &xopt, real_t &fopt,`  
`int &nacc, int &nfcnev, int &nobds)`

*Simulated annealing optimization solver.*

- `template<class OPT_>`  
`int OptimTN (OPT_ &theOpt, Vect< real_t > &x, Vect< real_t > &low, Vect< real_t > &up,`  
`Vect< int > &pivot, int max_it, real_t toler, int msg_lvl)`

*Truncated Newton optimization solver.*

- `template<class T_ , class M_>`  
`int Richardson (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, real_t omega, int max_it,`  
`real_t toler, int verbose)`

*Richardson solver function.*

- `template<class T_>`  
`void Schur (SkMatrix< T_ > &A, SpMatrix< T_ > &U, SpMatrix< T_ > &L, SpMatrix< T_`  
`> &D, Vect< T_ > &b, Vect< T_ > &c)`

*Solve a linear system of equations with a 2x2-block matrix.*

- `template<class T_>`  
`void Schur (PETScMatrix< T_ > &A, PETScMatrix< T_ > &U, PETScMatrix< T_ > &L,`  
`PETScMatrix< T_ > &D, PETScVect< T_ > &b, PETScVect< T_ > &c)`

*Solve a linear system of equations with a 2x2-block matrix.*

- `template<class T_, class M_>`  
`int SSOR (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler, int verbose)`

*SSOR solver function.*

- `ostream & operator<< (ostream &s, const TimeStepping &ts)`

*Output differential system information.*

- `void banner (const string &prog=" ")`

*Outputs a banner as header of any developed program.*

- `template<class T_>`  
`void QuickSort (std::vector< T_ > &a, int begin, int end)`

*Function to sort a vector.*

- `template<class T_>`  
`void qksort (std::vector< T_ > &a, int begin, int end)`

*Function to sort a vector.*

- `template<class T_, class C_>`  
`void qksort (std::vector< T_ > &a, int begin, int end, C_ compare)`

*Function to sort a vector according to a key function.*

- `int Sgn (real_t a)`

*Return sign of  $a$ : -1 or 1.*

- `real_t Abs2 (complex_t a)`

*Return square of modulus of complex number  $a$*

- `real_t Abs2 (real_t a)`

*Return square of real number  $a$*

- `real_t Abs (real_t a)`

*Return absolute value of  $a$*

- `real_t Abs (complex_t a)`

*Return modulus of complex number  $a$*

- `real_t Abs (const Point< real_t > &p)`

*Return Norm of vector  $a$*

- `real_t Conjg (real_t a)`

*Return complex conjugate of real number  $a$*

- `complex_t Conjg (complex_t a)`

*Return complex conjugate of complex number  $a$*

- `real_t Max (real_t a, real_t b, real_t c)`

*Return maximum value of real numbers  $a$ ,  $b$  and  $c$*

- `int Max (int a, int b, int c)`

*Return maximum value of integer numbers  $a$ ,  $b$  and  $c$*

- `real_t Min (real_t a, real_t b, real_t c)`

*Return minimum value of real numbers  $a$ ,  $b$  and  $c$*

- `int Min (int a, int b, int c)`

*Return minimum value of integer numbers  $a$ ,  $b$  and  $c$*

- `real_t Max (real_t a, real_t b, real_t c, real_t d)`

*Return maximum value of integer numbers  $a$ ,  $b$ ,  $c$  and  $d$*

- `int Max (int a, int b, int c, int d)`

*Return maximum value of integer numbers  $a$ ,  $b$ ,  $c$  and  $d$*

- `real_t Min (real_t a, real_t b, real_t c, real_t d)`



- Return minimum value of real numbers  $a$ ,  $b$ ,  $c$  and  $d$*

  - `int Min (int a, int b, int c, int d)`
- Return minimum value of integer numbers  $a$ ,  $b$ ,  $c$  and  $d$*

  - `real.t Arg (complex.t x)`
- Return argument of complex number  $x$*

  - `complex.t Log (complex.t x)`
- Return principal determination of logarithm of complex number  $x$*

  - `template<class T_>`  
`T_ Sqr (T_ x)`
- Return square of value  $x$*

  - `template<class T_>`  
`void Scale (T_ a, const vector< T_ > &x, vector< T_ > &y)`
- Multiply vector  $x$  by  $a$  and save result in vector  $y$*

  - `template<class T_>`  
`void Scale (T_ a, const Vect< T_ > &x, Vect< T_ > &y)`
- Multiply vector  $x$  by  $a$  and save result in vector  $y$*

  - `template<class T_>`  
`void Scale (T_ a, vector< T_ > &x)`
- Multiply vector  $x$  by  $a$*

  - `template<class T_>`  
`void Xpy (size.t n, T_ *x, T_ *y)`
- Add array  $x$  to  $y$*

  - `template<class T_>`  
`void Xpy (const vector< T_ > &x, vector< T_ > &y)`
- Add vector  $x$  to  $y$*

  - `template<class T_>`  
`void Axy (size.t n, T_ a, T_ *x, T_ *y)`
- Multiply array  $x$  by  $a$  and add result to  $y$*

  - `template<class T_>`  
`void Axy (T_ a, const vector< T_ > &x, vector< T_ > &y)`
- Multiply vector  $x$  by  $a$  and add result to  $y$*

  - `template<class T_>`  
`void Axy (T_ a, const Vect< T_ > &x, Vect< T_ > &y)`
- Multiply vector  $x$  by  $a$  and add result to  $y$*

  - `template<class T_>`  
`void Copy (size.t n, T_ *x, T_ *y)`
- Copy array  $x$  to  $y$   $n$  is the arrays size.*

  - `real.t Error2 (const vector< real.t > &x, const vector< real.t > &y)`
- Return absolute L2 error between vectors  $x$  and  $y$*

  - `real.t RError2 (const vector< real.t > &x, const vector< real.t > &y)`
- Return absolute  $L^2$  error between vectors  $x$  and  $y$*

  - `real.t ErrorMax (const vector< real.t > &x, const vector< real.t > &y)`
- Return absolute Max. error between vectors  $x$  and  $y$*

  - `real.t RErrorMax (const vector< real.t > &x, const vector< real.t > &y)`
- Return relative Max. error between vectors  $x$  and  $y$*

  - `template<class T_>`  
`T_ Dot (size.t n, T_ *x, T_ *y)`
- Return dot product of arrays  $x$  and  $y$*



- **real.t operator\*** (const vector< **real.t** > &x, const vector< **real.t** > &y)  
*Operator \* (Dot product of 2 vector instances)*
- **real.t Dot** (const vector< **real.t** > &x, const vector< **real.t** > &y)  
*Return dot product of vectors  $x$  and  $y$ .*
- **real.t Dot** (const **Vect**< **real.t** > &x, const **Vect**< **real.t** > &y)  
*Return dot product of vectors  $x$  and  $y$*
- template<class T\_ >  
**T\_ Dot** (const **Point**< T\_ > &x, const **Point**< T\_ > &y)  
*Return dot product of  $x$  and  $y$*
- template<class T\_ >  
**void Assign** (vector< T\_ > &v, const T\_ &a)  
*Assign the value  $a$  to all entries of a vector  $v$*
- template<class T\_ >  
**void Clear** (vector< T\_ > &v)  
*Assign 0 to all entries of a vector.*
- template<class T\_ >  
**void Clear** (**Vect**< T\_ > &v)  
*Assign 0 to all entries of a vector.*
- **real.t Nrm2** (size\_t n, **real.t** \*x)  
*Return 2-norm of array  $x$*
- **real.t Nrm2** (const vector< **real.t** > &x)  
*Return 2-norm of vector  $x$*
- template<class T\_ >  
**real.t Nrm2** (const **Point**< T\_ > &a)  
*Return 2-norm of  $a$*
- **bool Equal** (**real.t** x, **real.t** y, **real.t** toler=OFELLEPSMCH)  
*Function to return true if numbers  $x$  and  $y$  are close up to a given tolerance  $toler$*
- **char itoc** (int i)  
*Function to convert an integer to a character.*
- **std::string itos** (size\_t i)  
*Function to convert an integer to a string.*
- template<class T\_ >  
**T\_ stringTo** (const std::string &s)  
*Function to convert a string to a template type parameter.*
- **void RTrim** (char \*s)  
*Function to remove blanks at the end of a string.*
- **void LTrim** (char \*s)  
*Function to remove blanks at the beginning of a string.*
- **void Trim** (char \*s)  
*Function to remove blanks at the beginning and end of a string.*
- template<class T\_ >  
**void Swap** (T\_ &a, T\_ &b)  
*Swap elements  $a$  and  $b$ .*

## Variables

- `Node * theNode`  
*A pointer to `Node`.*
- `Element * theElement`  
*A pointer to `Element`.*
- `Side * theSide`  
*A pointer to `Side`.*
- `Edge * theEdge`  
*A pointer to `Edge`.*
- `int theStep`  
*Time step counter.*
- `int theIteration`  
*Iteration counter.*
- `int NbTimeSteps`  
*Number of time steps.*
- `int MaxNbIterations`  
*Maximal number of iterations.*
- `int Verbosity`  
*Parameter for verbosity of message outputting.*
- `real_t theTimeStep`  
*Time step label.*
- `real_t theTime`  
*Time value.*
- `real_t theFinalTime`  
*Final time value.*
- `real_t theTolerance`  
*Tolerance value for convergence.*
- `real_t theDiscrepancy`  
*Value of discrepancy for an iterative procedure Its default value is 1. 0.*
- `bool Converged`  
*Boolean variable to say if an iterative procedure has converged.*
- `bool InitPetsc`

### 6.1.1 Detailed Description

A namespace to group all library classes, functions, ... Namespace `OFELI` groups all OFELI library classes, functions and global variables.

### 6.1.2 Enumeration Type Documentation

#### `enum PDE_Terms`

Enumerate variable that selects various terms in partial differential equations

Enumerator

`MASS` Consistent mass term  
`CONSISTENT_MASS` Consistent mass term  
`LUMPED_MASS` Lumped mass term

**CAPACITY** Consistent capacity term  
**CONSISTENT\_CAPACITY** Consistent capacity term  
**LUMPED\_CAPACITY** Lumped capacity term  
**VISCOSITY** Viscosity term  
**STIFFNESS** Stiffness term  
**DIFFUSION** Diffusion term  
**CONVECTION** Convection term  
**DEVIATORIC** Deviatoric term  
**DILATATION** Dilatational term  
**ELECTRIC** Electric term  
**MAGNETIC** Magnetic term  
**LOAD** Body load term  
**HEAT\_SOURCE** Body heat source term  
**BOUNDARY\_TRACTION** Boundary traction (pressure) term  
**HEAT\_FLUX** Boundary heat flux term  
**CONTACT** Signorini contact  
**BUOYANCY** Buoyancy force term  
**LORENTZ\_FORCE** Lorentz force term

### enum EqDataType

Enumerate variable that selects equation data type

Enumerator

**INITIAL\_FIELD** Initial condition  
**SOLUTION** Solution vector (same as Initial)  
**INITIAL\_AUX\_1** Initial auxiliary field  
**INITIAL\_AUX\_2** Initial auxiliary field  
**INITIAL\_AUX\_3** Initial auxiliary field  
**INITIAL\_AUX\_4** Initial auxiliary field  
**BOUNDARY\_CONDITION** Boundary condition data  
**BODY\_FORCE** Body force data  
**SOURCE** Source data (same as Body force)  
**POINT\_FORCE** Localized (at point) force  
**BOUNDARY\_FORCE** Boundary force data  
**FLUX** Flux data (same as Boundary force)  
**TRACTION** Traction data (same as Boundary force)  
**AUX\_INPUT\_FIELD\_1** Auxiliary input field 1  
**AUX\_INPUT\_FIELD\_2** Auxiliary input field 2  
**AUX\_INPUT\_FIELD\_3** Auxiliary input field 3  
**AUX\_INPUT\_FIELD\_4** Auxiliary input field 4  
**DISPLACEMENT\_FIELD** A displacement field  
**VELOCITY\_FIELD** A velocity field  
**TEMPERATURE\_FIELD** A temperature field

**enum ArrayType**

Selects local or global option for array as argument.

Enumerator

*LOCAL\_ARRAY* For a local array labeled with local numbering

*GLOBAL\_ARRAY* For a local array labeled with global numbering

**enum TimeScheme**

Selects time integration scheme

Enumerator

*STATIONARY* No time scheme: stationary

*FORWARD\_EULER* Forward Euler scheme (Explicit)

*BACKWARD\_EULER* Backward Euler scheme (Implicit)

*CRANK\_NICOLSON* Crank-Nicolson scheme

*HEUN* Heun scheme

*NEWMARK* Newmark scheme

*LEAP\_FROG* Leap Frog scheme

*ADAMS\_BASHFORTH* Adams-Bashforth scheme (2nd Order)

*AB2* Adams-Bashforth scheme (2nd Order)

*RUNGE\_KUTTA* 4-th Order Runge-Kutta scheme (4th Order)

*RK4* 4-th Order Runge-Kutta scheme

*RK3\_TVD* 3-rd Order Runge-Kutta TVD scheme

*BDF2* Backward Difference Formula (2nd Order)

**enum PDE**

Choose partial differential equation to ‘

Enumerator

*LAPLACE* Laplace equation

*DIFFUSION\_CONVECTION* Diffusion Convection equation

*THERMAL\_PHASE\_CHANGE* Thermal phase change problem (Stefan)

*INCOMPRESSIBLE\_NAVIER\_STOKES* Incompressible Navier-Stokes equations

*LINEARIZED\_ELASTICITY* Linearized elasticity equations

*PLANAR\_TRUSS* 2-D truss equation

*SPATIAL\_BEAM* 3-D beam equations

**enum FEType**

Choose Finite [Element](#) Type

Enumerator

*FE\_2D\_3N* 2-D elements, 3-Nodes (P1)  
*FE\_2D\_6N* 2-D elements, 6-Nodes (P2)  
*FE\_2D\_4N* 2-D elements, 4-Nodes (Q1)  
*FE\_3D\_AXI\_3N* 3-D Axisymmetric elements, 3-Nodes (P1)  
*FE\_3D\_4N* 3-D elements, 4-Nodes (P1)  
*FE\_3D\_8N* 3-D elements, 8-Nodes (Q1)

**enum AnalysisType**

Choose analysis type

Enumerator

*STEADY\_STATE* Steady state analysis  
*TRANSIENT* Transient analysis  
*OPTIMIZATION* Optimization analysis

**enum MatrixType**

Choose matrix storage and type

Enumerator

*SKYLINE* Skyline storage  
*SPARSE* Sparse storage  
*DIAGONAL* Diagonal storage  
*TRIDIAGONAL* Tridiagonal storage  
*SYMMETRIC* Symmetric matrix  
*UNSYMMETRIC* Unsymmetric matrix  
*IDENTITY* Identity matrix

**enum Iteration**

Choose iterative solver for the linear system.

Enumerator

*DIRECT\_SOLVER* Direct solver  
*CG\_SOLVER* CG Method  
*CGS\_SOLVER* CGS Method  
*BICG\_SOLVER* BiCG Method  
*BICG\_STAB\_SOLVER* BiCGStab Method  
*GMRES\_SOLVER* GMRes Method

**enum Preconditioner**

Choose preconditioner for the linear system.

Enumerator

*IDENT\_PREC* Identity (No preconditioning)  
*DIAG\_PREC* Diagonal preconditioner  
*DILU\_PREC* ILU (Incomplete factorization) preconditioner  
*ILU\_PREC* DILU (Diagonal Incomplete factorization) preconditioner  
*SSOR\_PREC* SSOR preconditioner

**enum BCType**

To select special boundary conditions.

Enumerator

*PERIODIC\_A* Periodic Boundary conditions (first side)  
*PERIODIC\_B* Periodic Boundary conditions (second side)  
*CONTACT\_BC* Contact Boundary conditions  
*SLIP* Slip Boundary conditions

**6.1.3 Function Documentation**

**T\_\* OFELI::A ( )**

Return element matrix.

Matrix is returned as a C-array

**T\_\* OFELI::b ( )**

Return element right-hand side.

Right-hand side is returned as a C-array

**T\_\* OFELI::Prev ( )**

Return element previous vector.

This is the vector given in time dependent constructor. It is returned as a C-array.

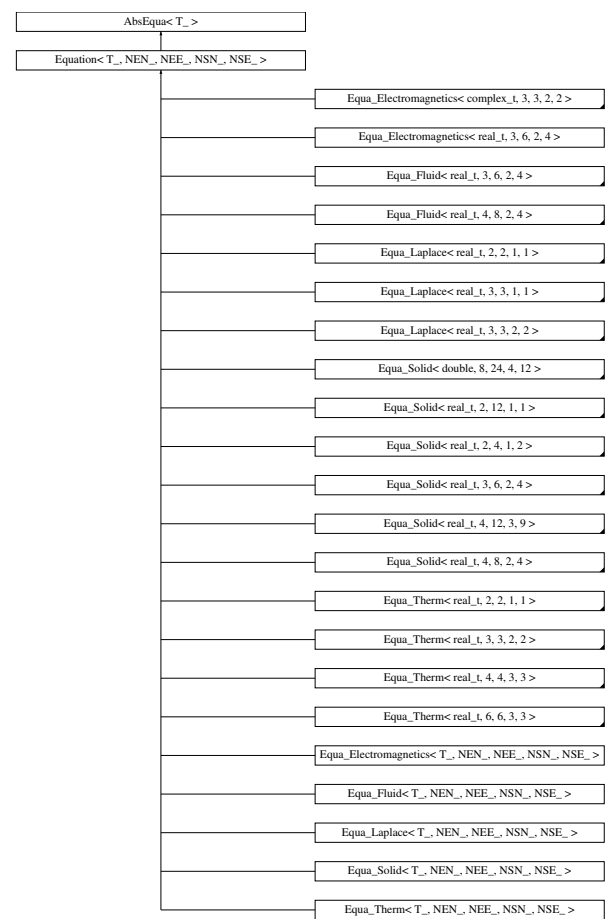


# Chapter 7

## Class Documentation

### 7.1 AbsEqua< T\_ > Class Template Reference

Mother abstract class to describe equation.  
Inheritance diagram for AbsEqua< T\_ >:



### Public Member Functions

- [AbsEqua\(\)](#)



*Default constructor.*

- [AbsEqua](#) ([Mesh](#) &mesh)

*Constructor with mesh instance.*

- virtual [~AbsEqua](#) ()

*Destructor.*

- void [setMesh](#) ([Mesh](#) &m)

*Define mesh and renumber DOFs after removing imposed ones.*

- [Mesh](#) & [getMesh](#) () const

*Return reference to [Mesh](#) instance.*

- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()

*Return reference to linear solver instance.*

- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))

*Choose solver for the linear system.*

- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)

*Solve the linear system.*

### 7.1.1 Detailed Description

**template<class T\_>class OFELI::AbsEqua< T\_ >**

Mother abstract class to describe equation.

Template Parameters

|                            |                                                 |
|----------------------------|-------------------------------------------------|
| <a href="#">&lt;T_&gt;</a> | Data type (real_t, float, complex<real_t>, ...) |
|----------------------------|-------------------------------------------------|

### 7.1.2 Member Function Documentation

**[Mesh](#)& [getMesh](#) ( ) const**

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )**

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )**

Solve the linear system.

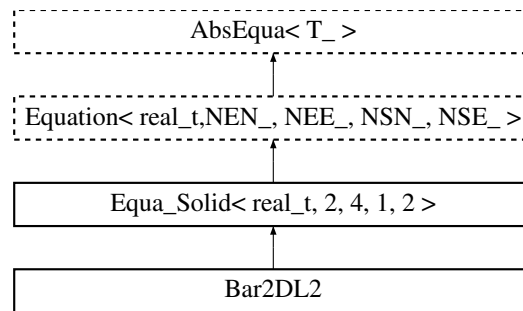
Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

## 7.2 Bar2DL2 Class Reference

To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node.

Inheritance diagram for Bar2DL2:



## Public Member Functions

- `Bar2DL2 ()`  
*Default Constructor.*
- `Bar2DL2 (Element *el, real_t section)`  
*Constructor using element data.*
- `~Bar2DL2 ()`  
*Destructor.*
- `void Mass (real_t coef=1.)`  
*Add element consistent mass contribution to matrix and right-hand side after multiplication by coef*
- `void LMass (real_t coef=1.)`  
*Add element lumped mass contribution to matrix and right-hand side after multiplication by coef*
- `void LMassToLHS (real_t coef=1)`  
*Add lumped mass matrix to left-hand side after multiplying it by coefficient coef*
- `void LMassToRHS (real_t coef=1)`  
*Add lumped mass contribution to right-hand side after multiplying it by coefficient coef*
- `void MassToLHS (real_t coef=1)`  
*Add consistent mass matrix to left-hand side after multiplying it by coefficient coef*
- `void MassToRHS (real_t coef=1)`  
*Add consistent mass contribution to right-hand side after multiplying it by coefficient coef*
- `void Stiffness (real_t coef=1.)`  
*Add element stiffness to left hand side.*
- `void BodyRHS (UserData< real_t > &ud)`  
*Add body right-hand side term to right hand side.*
- `real_t Stress () const`  
*Return stresses in bar.*
- `void getStresses (const Vect< real_t > &u, Vect< real_t > &s)`  
*Return stresses in the truss structure (elementwise)*
- `int runOneTimeStep ()`  
*Run one time step.*
- `int run ()`  
*Solve the equation.*
- `void build ()`  
*Build the linear system of equations.*
- `void buildEigen (SkSMatrix< real_t > &K, SkSMatrix< real_t > &M)`  
*Build global stiffness and mass matrices for the eigen system.*
- `void buildEigen (SkSMatrix< real_t > &K, Vect< real_t > &M)`

- Build global stiffness and mass matrices for the eigen system.*

  - void **setLumpedMass** ()  
*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
  - void **setMass** ()  
*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
  - virtual void **Deviator** (real\_t coef=1)  
*Add deviator matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
  - virtual void **Dilatation** (real\_t coef=1)  
*Add dilatation matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
  - virtual void **DilatationToRHS** (real\_t coef=1)  
*Add dilatation vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
  - virtual void **DeviatorToRHS** (real\_t coef=1)  
*Add deviator vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
  - virtual void **StiffnessToRHS** (real\_t coef=1)  
*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
  - void **setDilatation** ()  
*Add dilatation matrix to left and/or right-hand side taking into account time.*
  - void **setDeviator** ()  
*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
  - void **setStiffness** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
  - void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
  - void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
  - void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
  - void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
  - void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
  - void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
  - void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
  - void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
  - void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
  - void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
  - void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*

- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) (Matrix< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScVect< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) (BMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (TrMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (Vect< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) (PETScMatrix< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) (PETScVect< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) (Matrix< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (Vect< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) (Matrix< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (TrMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const Vect< T\_ > &x, Vect< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*

- void **AxbAssembly** (const **Side** &sd, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- void **setInitialSolution** (const **Vect**< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t **setMaterialProperty** (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void **setMesh** (**Mesh** &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- **Mesh** & **getMesh** () const  
*Return reference to **Mesh** instance.*
- **LinearSolver**< T\_ > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=**IDENT\_PREC**)  
*Choose solver for the linear system.*
- int **SolveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_, NEE\_ > **eMat**  
***LocalMatrix** instance containing local matrix associated to current element.*
- **LocalMatrix**< T\_, NSE\_, NSE\_ > **sMat**  
***LocalMatrix** instance containing local matrix associated to current side.*
- **LocalVect**< T\_, NEE\_ > **ePrev**  
***LocalVect** instance containing local vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRHS**  
***LocalVect** instance containing local right-hand side vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRes**  
***LocalVect** instance containing local residual vector associated to current element.*
- **LocalVect**< T\_, NSE\_ > **sRHS**  
***LocalVect** instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **Young** (const real\_t &E)  
*Set (constant) Young modulus.*
- void **Young** (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void **Poisson** (const real\_t &nu)  
*Set (constant) Poisson ratio.*
- void **Poisson** (const string &exp)  
*Set Poisson ratio given by an algebraic expression.*
- void **Density** (const real\_t &rho)

- *Set (constant) density.*  
void [Density](#) (const string &exp)
- *Set density given by an algebraic expression.*  
void [setMaterial](#) ()
- *Set material properties.*  
void [Init](#) (const [Element](#) \*el)
- *Set element arrays to zero.*  
void [Init](#) (const [Side](#) \*sd)
- *Set side arrays to zero.*

### 7.2.1 Detailed Description

To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node.

This class implements a planar (two-dimensional) elastic bar using 2-node lines. Note that members calculating element arrays have as an argument a real `coef` that is multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.2.2 Constructor & Destructor Documentation

**Bar2DL2 ( )**

Default Constructor.

Constructs an empty equation.

**Bar2DL2 ( [Element](#) \* *el*, [real.t](#) *section* )**

Constructor using element data.

Parameters

|                 |                      |                                    |
|-----------------|----------------------|------------------------------------|
| <code>in</code> | <code>el</code>      | Pointer to <a href="#">Element</a> |
| <code>in</code> | <code>section</code> | Section of bar at present element  |

### 7.2.3 Member Function Documentation

**void Mass ( [real.t](#) *coef* = 1. )** [virtual]

Add element consistent mass contribution to matrix and right-hand side after multiplication by `coef`

Parameters

|                 |                   |                                                     |
|-----------------|-------------------|-----------------------------------------------------|
| <code>in</code> | <code>coef</code> | Coefficient to multiply by added term [Default: 1]. |
|-----------------|-------------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< \[real.t\]\(#\), 2, 4, 1, 2 >](#).

**void LMass ( [real.t](#) *coef* = 1. )** [virtual]

Add element lumped mass contribution to matrix and right-hand side after multiplication by `coef`

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void LMassToLHS ( real.t coef = 1 )** [virtual]

Add lumped mass matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void LMassToRHS ( real.t coef = 1 )** [virtual]

Add lumped mass contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void MassToLHS ( real.t coef = 1 )** [virtual]

Add consistent mass matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void MassToRHS ( real.t coef = 1 )** [virtual]

Add consistent mass contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void Stiffness ( real.t coef = 1. )** [virtual]

Add element stiffness to left hand side.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real.t, 2, 4, 1, 2 >](#).

**void BodyRHS ( UserData< real.t > & ud )**

Add body right-hand side term to right hand side.

Parameters

|           |           |                                                     |
|-----------|-----------|-----------------------------------------------------|
| <b>in</b> | <i>ud</i> | instance containing user data with prescribes loads |
|-----------|-----------|-----------------------------------------------------|

**void getStresses ( const Vect< real.t > & u, Vect< real.t > & s )**

Return stresses in the truss structure (elementwise)



## Parameters

|    |     |                                                                     |
|----|-----|---------------------------------------------------------------------|
| in | $u$ | <a href="#">Vect</a> instance containing displacements at nodes     |
| in | $s$ | <a href="#">Vect</a> instance containing axial stresses in elements |

**int runOneTimeStep ( )**

Run one time step.

This function performs one time step in equation solving. It is to be used only if a TRANSIENT analysis is required.

## Returns

Return error from the linear system solver

**int run ( )**

Solve the equation.

If the analysis (see function **setAnalysis**) is STEADY\_STATE, then the function solves the stationary equation.

If the analysis is TRANSIENT, then the function performs time stepping until the final time is reached.

**void build ( )**

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent mass matrix
- The choice of desired linear system solver

**void buildEigen ( SkSMatrix< real.t > & K, SkSMatrix< real.t > & M )**

Build global stiffness and mass matrices for the eigen system.

Case where the mass matrix is consistent

## Parameters

|    |     |                        |
|----|-----|------------------------|
| in | $K$ | Stiffness matrix       |
| in | $M$ | Consistent mass matrix |

**void buildEigen ( SkSMatrix< real.t > & K, Vect< real.t > & M )**

Build global stiffness and mass matrices for the eigen system.

Case where the mass matrix is lumped

## Parameters

|    |     |                                        |
|----|-----|----------------------------------------|
| in | $K$ | Stiffness matrix                       |
| in | $M$ | Vector containing diagonal mass matrix |

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE_FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT_FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE_FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|  |          |                                                               |
|--|----------|---------------------------------------------------------------|
|  | <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|--|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | Global vector ( <a href="#">Vect</a> instance) |
|----|----------|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

## 7.2.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

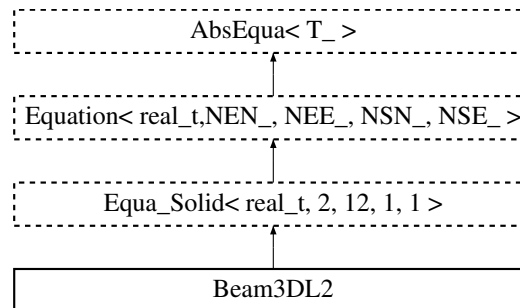
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.3 Beam3DL2 Class Reference

To build element equations for 3-D beam equations using 2-node lines.

Inheritance diagram for Beam3DL2:



### Public Member Functions

- [Beam3DL2](#) ()  
*Default Constructor.*
- [Beam3DL2](#) ([Element](#) \*el, [real\\_t](#) A, [real\\_t](#) I1, [real\\_t](#) I2)  
*Constructor using element data.*
- [Beam3DL2](#) ([Element](#) \*el, [real\\_t](#) A, [real\\_t](#) I1, [real\\_t](#) I2, const [Vect](#)< [real\\_t](#) > &u, const [real\\_t](#) &time=0)  
*Constructor for dynamic problems.*
- [Beam3DL2](#) ([Mesh](#) &ms, const [Vect](#)< [real\\_t](#) > &u, [Vect](#)< [real\\_t](#) > &d)  
*Constructor to determine displacements.*
- [~Beam3DL2](#) ()  
*Destructor.*
- void [LMassToLHS](#) ([real\\_t](#) coef=1.)  
*Add element lumped Mass contribution to matrix after multiplication by coef*
- void [LMassToRHS](#) ([real\\_t](#) coef=1.)  
*Add element lumped Mass contribution to RHS after multiplication by coef*
- void [MassToLHS](#) ([real\\_t](#) coef=1.)  
*Add element consistent Mass contribution to matrix after multiplication by coef (not implemented)*
- void [MassToRHS](#) ([real\\_t](#) coef=1.)  
*Add element consistent Mass contribution to RHS after multiplication by coef (not implemented)*
- void [Stiffness](#) ([real\\_t](#) coef=1.)  
*Add element stiffness to left hand side.*
- void [Load](#) (const [Vect](#)< [real\\_t](#) > &f)  
*Add contributions for loads.*
- void [setBending](#) ()  
*Set bending contribution to stiffness.*
- void [setAxial](#) ()  
*Set axial contribution to stiffness.*
- void [setShear](#) ()  
*Set shear contribution to stiffness.*
- void [setTorsion](#) ()

- *Set torsion contribution to stiffness.*  
 • void [setNoBending](#) ()
- *Set no bending contribution.*  
 • void [setNoAxial](#) ()
- *Set no axial contribution.*  
 • void [setNoShear](#) ()
- *Set no shear contribution.*  
 • void [setNoTorsion](#) ()
- *Set no torsion contribution.*  
 • void [setReducedIntegration](#) ()
- *Set reduced integration.*  
 • [real.t AxialForce](#) () const
- *Return axial force in element.*  
 • [Point< real.t > ShearForce](#) () const
- *Return shear force in element.*  
 • [Point< real.t > BendingMoment](#) () const
- *Return bending moment in element.*  
 • [real.t TwistingMoment](#) () const
- *Return twisting moment in element.*  
 • void [buildEigen](#) ([SkSMatrix< real.t > &K](#), [Vect< real.t > &M](#))
- *Build global stiffness and mass matrices for the eigen system.*  
 • void [setLumpedMass](#) ()
- *Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*  
 • void [setMass](#) ()
- *Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*  
 • virtual void [Mass](#) ([real.t](#) coef=1)
- *Add consistent mass matrix to left-hand side after multiplication by coef [Default: 1].*  
 • virtual void [LMass](#) ([real.t](#) coef=1)
- *Add lumped mass matrix to left-hand side after multiplication by coef [Default: 1].*  
 • virtual void [Deviator](#) ([real.t](#) coef=1)
- *Add deviator matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*  
 • virtual void [Dilatation](#) ([real.t](#) coef=1)
- *Add dilatation matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*  
 • virtual void [DilatationToRHS](#) ([real.t](#) coef=1)
- *Add dilatation vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*  
 • virtual void [DeviatorToRHS](#) ([real.t](#) coef=1)
- *Add deviator vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*  
 • virtual void [StiffnessToRHS](#) ([real.t](#) coef=1)
- *Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*  
 • void [setDilatation](#) ()
- *Add dilatation matrix to left and/or right-hand side taking into account time.*  
 • void [setDeviator](#) ()
- *Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*

- void `setStiffness` ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void `updateBC` (const `Element` &el, const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `updateBC` (const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `DiagBC` (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void `LocalNodeVector` (`Vect`< T\_ > &b)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be, int dof)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NSE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize `Element` Vector.*
- void `SideVector` (const `Vect`< T\_ > &b)  
*Localize `Side` Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()  
*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix`< T\_ > \*A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScVect`< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SpMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`TrMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`Vect`< T\_ > &v)  
*Assemble element vector into global one.*
- void `SideAssembly` (`PETScMatrix`< T\_ > &A)  
*Assemble side matrix into global one.*

- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > **eMat**  
*LocalMatrix* instance containing local matrix associated to current element.
- **LocalMatrix**< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > **sMat**  
*LocalMatrix* instance containing local matrix associated to current side.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **ePrev**  
*LocalVect* instance containing local vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRHS**  
*LocalVect* instance containing local right-hand side vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRes**  
*LocalVect* instance containing local residual vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NSE<sub>-</sub> > **sRHS**  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void **Young** (const **real.t** &E)  
*Set (constant) Young modulus.*
- void **Young** (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void **Poisson** (const **real.t** &nu)  
*Set (constant) Poisson ratio.*
- void **Poisson** (const string &exp)  
*Set Poisson ratio given by an algebraic expression.*
- void **Density** (const **real.t** &rho)  
*Set (constant) density.*
- void **Density** (const string &exp)  
*Set density given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.3.1 Detailed Description

To build element equations for 3-D beam equations using 2-node lines.

This class enables building finite element arrays for 3-D beam elements using 6 degrees of freedom per node and 2-Node line elements.

### 7.3.2 Constructor & Destructor Documentation

**Beam3DL2** ( **Element** \* el, **real.t** A, **real.t** I1, **real.t** I2 )

Constructor using element data.

Parameters

|    |           |                                    |
|----|-----------|------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a> |
| in | <i>A</i>  | Section area of the beam           |
| in | <i>I1</i> | first (x) momentum of inertia      |
| in | <i>I2</i> | second (y) momentum of inertia     |

**Beam3DL2 ( [Element](#) \* *el*, real\_t *A*, real\_t *I1*, real\_t *I2*, const Vect< real\_t > & *u*, const real\_t & *time* = 0 )**

Constructor for dynamic problems.

Parameters

|    |             |                                                             |
|----|-------------|-------------------------------------------------------------|
| in | <i>el</i>   | Pointer to <a href="#">Element</a>                          |
| in | <i>A</i>    | Section area of the beam                                    |
| in | <i>I1</i>   | first (x) momentum of inertia                               |
| in | <i>I2</i>   | second (y) momentum of inertia                              |
| in | <i>u</i>    | Vector containing previous solution (at previous time step) |
| in | <i>time</i> | Current time value                                          |

**Beam3DL2 ( [Mesh](#) & *ms*, const Vect< real\_t > & *u*, Vect< real\_t > & *d* )**

Constructor to determine displacements.

The unknowns consist in planar and rotational degrees of freedom. This member function construct a 3-D node vector that gives the displacement vector at each node.

Parameters

|     |           |                                                                                     |
|-----|-----------|-------------------------------------------------------------------------------------|
| in  | <i>ms</i> | <a href="#">Mesh</a> instance                                                       |
| in  | <i>u</i>  | Vector containing the solution vector                                               |
| out | <i>d</i>  | Vector containing three components for each node that are x, y and z displacements. |

### 7.3.3 Member Function Documentation

**void buildEigen ( [SkSMatrix](#)< real\_t > & *K*, Vect< real\_t > & *M* )**

Build global stiffness and mass matrices for the eigen system.

Case where the mass matrix is lumped

Parameters

|    |          |                                        |
|----|----------|----------------------------------------|
| in | <i>K</i> | Stiffness matrix                       |
| in | <i>M</i> | Vector containing diagonal mass matrix |

**void updateBC ( const [Element](#) & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                       |
|----|-----------|---------------------------------------|
| in | <i>el</i> | Reference to current element instance |
|----|-----------|---------------------------------------|



|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |
|-----------|-----------|-------------------------------------------------|

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |
|-----------|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|           |                 |                                                                                                                                                                                                                                                                                                                  |
|-----------|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| <b>in</b> | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|           |          |                                                                                                                                                                                                                        |
|-----------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|-----------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|           |          |                                |
|-----------|----------|--------------------------------|
| <b>in</b> | <i>b</i> | Global vector to be localized. |
|-----------|----------|--------------------------------|

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |
|-----|-----------|-----------------------------------------------------------------------------|

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

## Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( [Matrix](#)<  $T_{-}$  > \*  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( [SkSMatrix](#)<  $T_{-}$  > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( [SkMatrix](#)<  $T_{-}$  > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( [SpMatrix](#)<  $T_{-}$  > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( [TrMatrix](#)<  $T_{-}$  > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real.t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

## Parameters

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | ls | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | pc | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

## Parameters

|        |   |                                                                                 |
|--------|---|---------------------------------------------------------------------------------|
| in     | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | b | Vector containing right-hand side                                               |
| in,out | x | Vector containing initial guess of solution on input, actual solution on output |

### 7.3.4 Member Data Documentation

**LocalVect<T\_,NEE-> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.4 BiotSavart Class Reference

Class to compute the magnetic induction from the current density using the Biot-Savart formula.

### Public Member Functions

- [BiotSavart](#) ()

*Default constructor.*

- **BiotSavart** (**Mesh** &ms)

*Constructor using mesh data.*

- **BiotSavart** (**Mesh** &ms, const **Vect**< **real\_t** > &J, **Vect**< **real\_t** > &B, int code=0)

*Constructor using mesh and vector of real current density.*

- **BiotSavart** (**Mesh** &ms, const **Vect**< **complex\_t** > &J, **Vect**< **complex\_t** > &B, int code=0)

*Constructor using mesh and vector of complex current density.*

- **~BiotSavart** ()

*Destructor.*

- void **setCurrentDensity** (const **Vect**< **real\_t** > &J)

*Set (real) current density given at elements.*

- void **setCurrentDensity** (const **Vect**< **complex\_t** > &J)

*Set (real) current density given at elements.*

- void **setMagneticInduction** (**Vect**< **real\_t** > &B)

*Transmit (real) magnetic induction vector given at nodes.*

- void **setMagneticInduction** (**Vect**< **complex\_t** > &B)

*Transmit (complex) magnetic induction vector given at nodes.*

- void **selectCode** (int code)

*Choose code of faces or edges at which current density is given.*

- void **setPermeability** (**real\_t** mu)

*Set the magnetic permeability coefficient.*

- void **setBoundary** ()

*Choose to compute the magnetic induction at boundary nodes only.*

- **Point**< **real\_t** > **getB3** (**Point**< **real\_t** > x)

*Compute the real magnetic induction at a given point using the volume Biot-Savart formula.*

- **Point**< **real\_t** > **getB2** (**Point**< **real\_t** > x)

*Compute the real magnetic induction at a given point using the surface Biot-Savart formula.*

- **Point**< **real\_t** > **getB1** (**Point**< **real\_t** > x)

*Compute the real magnetic induction at a given point using the line Biot-Savart formula.*

- **Point**< **complex\_t** > **getBC3** (**Point**< **real\_t** > x)

*Compute the complex magnetic induction at a given point using the volume Biot-Savart formula.*

- **Point**< **complex\_t** > **getBC2** (**Point**< **real\_t** > x)

*Compute the complex magnetic induction at a given point using the surface Biot-Savart formula.*

- **Point**< **complex\_t** > **getBC1** (**Point**< **real\_t** > x)

*Compute the complex magnetic induction at a given point using the line Biot-Savart formula.*

- int **run** ()

*Run the calculation by the Biot-Savart formula.*

### 7.4.1 Detailed Description

Class to compute the magnetic induction from the current density using the Biot-Savart formula.

Given a current density vector given at elements, a collection of sides of edges (piecewise constant), this class enables computing the magnetic induction vector (continuous and piecewise linear) using the Ampere equation. This magnetic induction is obtained by using the Biot-Savart formula which can be either a volume, surface or line formula depending on the nature of the current density vector.

### 7.4.2 Constructor & Destructor Documentation

**BiotSavart ( Mesh & *ms* )**

Constructor using mesh data.

Parameters

|                 |                 |                               |
|-----------------|-----------------|-------------------------------|
| <code>in</code> | <code>ms</code> | <a href="#">Mesh</a> instance |
|-----------------|-----------------|-------------------------------|

**BiotSavart ( Mesh & *ms*, const Vect< real.t > & *J*, Vect< real.t > & *B*, int *code* = 0 )**

Constructor using mesh and vector of real current density.

The current density is assumed piecewise constant

Parameters

|                 |                   |                                                                                                                    |
|-----------------|-------------------|--------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>ms</code>   | <a href="#">Mesh</a> instance                                                                                      |
| <code>in</code> | <code>J</code>    | Sidewise vector of current density ( <i>J</i> is a real valued vector), in the case of a surface supported current |
| <code>in</code> | <code>B</code>    | Nodewise vector that contains, once the member function run is used, the magnetic induction                        |
| <code>in</code> | <code>code</code> | Only sides with given <i>code</i> support current [Default: 0]                                                     |

**BiotSavart ( Mesh & *ms*, const Vect< complex.t > & *J*, Vect< complex.t > & *B*, int *code* = 0 )**

Constructor using mesh and vector of complex current density.

The current density is assumed piecewise constant

Parameters

|                 |                   |                                                                                                                       |
|-----------------|-------------------|-----------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>ms</code>   | <a href="#">Mesh</a> instance                                                                                         |
| <code>in</code> | <code>J</code>    | Sidewise vector of current density ( <i>J</i> is a complex valued vector), in the case of a surface supported current |
| <code>in</code> | <code>B</code>    | Nodewise vector that contains, once the member function run is used, the magnetic induction                           |
| <code>in</code> | <code>code</code> | Only sides with given <i>code</i> support current [Default: 0]                                                        |

### 7.4.3 Member Function Documentation

**void setCurrentDensity ( const Vect< real.t > & *J* )**

Set (real) current density given at elements.

The current density is assumed piecewise constant and real valued. This function can be used in the case of the volume Biot-Savart formula.

Parameters

|                 |                |                                                                          |
|-----------------|----------------|--------------------------------------------------------------------------|
| <code>in</code> | <code>J</code> | Current density vector ( <a href="#">Vect</a> instance) and real entries |
|-----------------|----------------|--------------------------------------------------------------------------|

**void setCurrentDensity ( const Vect< complex.t > & *J* )**

Set (real) current density given at elements.

The current density is assumed piecewise constant and complex valued. This function can be used in the case of the volume Biot-Savart formula.

Parameters

|                 |                |                                                                            |
|-----------------|----------------|----------------------------------------------------------------------------|
| <code>in</code> | <code>J</code> | Current density vector ( <a href="#">Vect</a> instance) of complex entries |
|-----------------|----------------|----------------------------------------------------------------------------|

**void setMagneticInduction ( Vect< real.t > & *B* )**

Transmit (real) magnetic induction vector given at nodes.

Parameters

|     |     |                                                                             |
|-----|-----|-----------------------------------------------------------------------------|
| out | $B$ | Magnetic induction vector ( <a href="#">Vect</a> instance) and real entries |
|-----|-----|-----------------------------------------------------------------------------|

**void setMagneticInduction ( Vect< complex.t > & B )**

Transmit (complex) magnetic induction vector given at nodes.

Parameters

|     |     |                                                                                |
|-----|-----|--------------------------------------------------------------------------------|
| out | $B$ | Magnetic induction vector ( <a href="#">Vect</a> instance) and complex entries |
|-----|-----|--------------------------------------------------------------------------------|

**void setPermeability ( real.t  $\mu$  )**

Set the magnetic permeability coefficient.

Parameters

|    |       |                       |
|----|-------|-----------------------|
| in | $\mu$ | Magnetic permeability |
|----|-------|-----------------------|

**void setBoundary ( )**

Choose to compute the magnetic induction at boundary nodes only.

By default the magnetic induction is computed (using the function `run`) at all mesh nodes

Note

This function has no effect for surface of line Biot-Savart formula

**Point<real.t> getB3 ( Point< real.t > x )**

Compute the real magnetic induction at a given point using the volume Biot-Savart formula.

This function computes a real valued magnetic induction for a real valued current density field

Parameters

|    |     |                                                                  |
|----|-----|------------------------------------------------------------------|
| in | $x$ | Coordinates of point at which the magnetic induction is computed |
|----|-----|------------------------------------------------------------------|

Returns

Value of the magnetic induction at  $x$

**Point<real.t> getB2 ( Point< real.t > x )**

Compute the real magnetic induction at a given point using the surface Biot-Savart formula.

This function computes a real valued magnetic induction for a real valued current density field

Parameters

|    |     |                                                                  |
|----|-----|------------------------------------------------------------------|
| in | $x$ | Coordinates of point at which the magnetic induction is computed |
|----|-----|------------------------------------------------------------------|

Returns

Value of the magnetic induction at  $x$

**Point<real\_t> getB1 ( Point< real\_t > x )**

Compute the real magnetic induction at a given point using the line Biot-Savart formula.

This function computes a real valued magnetic induction for a real valued current density field

Parameters

|    |   |                                                                  |
|----|---|------------------------------------------------------------------|
| in | x | Coordinates of point at which the magnetic induction is computed |
|----|---|------------------------------------------------------------------|

Returns

Value of the magnetic induction at x

**Point<complex\_t> getBC3 ( Point< real\_t > x )**

Compute the complex magnetic induction at a given point using the volume Biot-Savart formula.

This function computes a complex valued magnetic induction for a complex valued current density field

Parameters

|    |   |                                                                  |
|----|---|------------------------------------------------------------------|
| in | x | Coordinates of point at which the magnetic induction is computed |
|----|---|------------------------------------------------------------------|

Returns

Value of the magnetic induction at x

**Point<complex\_t> getBC2 ( Point< real\_t > x )**

Compute the complex magnetic induction at a given point using the surface Biot-Savart formula.

This function computes a complex valued magnetic induction for a complex valued current density field

Parameters

|    |   |                                                                  |
|----|---|------------------------------------------------------------------|
| in | x | Coordinates of point at which the magnetic induction is computed |
|----|---|------------------------------------------------------------------|

Returns

Value of the magnetic induction at x

**Point<complex\_t> getBC1 ( Point< real\_t > x )**

Compute the complex magnetic induction at a given point using the line Biot-Savart formula.

This function computes a complex valued magnetic induction for a complex valued current density field

Parameters

|    |   |                                                                  |
|----|---|------------------------------------------------------------------|
| in | x | Coordinates of point at which the magnetic induction is computed |
|----|---|------------------------------------------------------------------|

Returns

Value of the magnetic induction at x

**int run ( )**

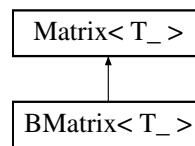
Run the calculation by the Biot-Savart formula.

This function computes the magnetic induction, which is stored in the vector B given in the constructor

## 7.5 BMatrix< T\_ > Class Template Reference

To handle band matrices.

Inheritance diagram for BMatrix< T\_ >:



### Public Member Functions

- **BMatrix ( )**  
*Default constructor.*
- **BMatrix (size\_t size, int ld, int ud)**  
*Constructor that for a band matrix with given size and bandwidth.*
- **BMatrix (const BMatrix &m)**  
*Copy Constructor.*
- **~BMatrix ( )**  
*Destructor.*
- **void setSize (size\_t size, int ld, int ud)**  
*Set size (number of rows) and storage of matrix.*
- **void MultAdd (const Vect< T\_ > &x, Vect< T\_ > &y) const**  
*Multiply matrix by vector x and add result to y*
- **void MultAdd (T\_ a, const Vect< T\_ > &x, Vect< T\_ > &y) const**  
*Multiply matrix by vector a\*x and add result to y*
- **void Mult (const Vect< T\_ > &x, Vect< T\_ > &y) const**  
*Multiply matrix by vector x and save result in y*
- **void TMult (const Vect< T\_ > &x, Vect< T\_ > &y) const**  
*Multiply transpose of matrix by vector x and save result in y*
- **void Apxy (T\_ a, const BMatrix< T\_ > &x)**  
*Add to matrix the product of a matrix by a scalar.*
- **void Apxy (T\_ a, const Matrix< T\_ > \*x)**  
*Add to matrix the product of a matrix by a scalar.*
- **void set (size\_t i, size\_t j, const T\_ &val)**  
*Add constant val to an entry (i, j) of the matrix.*
- **void add (size\_t i, size\_t j, const T\_ &val)**  
*Add constant val value to an entry (i, j) of the matrix.*
- **T\_ operator() (size\_t i, size\_t j) const**  
*Operator () (Constant version).*
- **T\_ & operator() (size\_t i, size\_t j)**



- Operator () (Non constant version).
- **BMatrix**< T\_ > & **operator=** (const **BMatrix**< T\_ > &m)  
Operator =.
- **BMatrix**< T\_ > & **operator=** (const T\_ &x)  
Operator = Assign matrix to identity times x.
- **BMatrix**< T\_ > & **operator\*=** (const T\_ &x)  
Operator \*.
- **BMatrix**< T\_ > & **operator+=** (const T\_ &x)  
Operator +=.
- int **setLU** ()  
Factorize the matrix (LU factorization)
- int **solve** (**Vect**< T\_ > &b)
- int **solve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
Solve linear system.
- T\_ \* **get** () const  
Return C-Array.
- T\_ **get** (size\_t i, size\_t j) const  
Return entry (i, j) of matrix.
- size\_t **getNbRows** () const  
Return number of rows.
- size\_t **getNbColumns** () const  
Return number of columns.
- void **setPenal** (real\_t p)  
Set Penalty Parameter (For boundary condition prescription).
- void **setDiagonal** ()  
Set the matrix as diagonal.
- void **setDiagonal** (**Mesh** &mesh)  
Initialize matrix storage in the case where only diagonal terms are stored.
- T\_ **getDiag** (size\_t k) const  
Return k-th diagonal entry of matrix.
- size\_t **size** () const  
Return matrix dimension (Number of rows and columns).
- void **Assembly** (const **Element** &el, T\_ \*a)  
Assembly of element matrix into global matrix.
- void **Assembly** (const **Element** &el, const **DMatrix**< T\_ > &a)  
Assembly of element matrix into global matrix.
- void **Assembly** (const **Side** &sd, T\_ \*a)  
Assembly of side matrix into global matrix.
- void **Assembly** (const **Side** &sd, const **DMatrix**< T\_ > &a)  
Assembly of side matrix into global matrix.
- void **Prescribe** (**Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
Impose by a penalty method an essential boundary condition, using the **Mesh** instance provided by the constructor.
- void **Prescribe** (int dof, int code, **Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.
- void **Prescribe** (**Vect**< T\_ > &b, int flag=0)

- Impose by a penalty method a homogeneous (=0) essential boundary condition.*
- void **Prescribe** (size\_t dof, **Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- void **PrescribeSide** ()  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- virtual int **Factor** ()=0  
*Factorize matrix. Available only if the storage class enables it.*
- int **FactorAndSolve** (**Vect**< T\_ > &b)
- Factorize matrix and solve the linear system.*
- int **FactorAndSolve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)
- Factorize matrix and solve the linear system.*
- size\_t **getLength** () const  
*Return number of stored terms in matrix.*
- int **isDiagonal** () const  
*Say if matrix is diagonal or not.*
- int **isFactorized** () const  
*Say if matrix is factorized or not.*
- virtual size\_t **getColInd** (size\_t i) const  
*Return Column index for column i (See the description for class [SpMatrix](#)).*
- virtual size\_t **getRowPtr** (size\_t i) const  
*Return Row pointer for row i (See the description for class [SpMatrix](#)).*
- T\_ **operator**() (size\_t i) const  
*Operator () with one argument (Constant version).*
- T\_ & **operator**() (size\_t i)  
*Operator () with one argument (Non Constant version).*
- T\_ & **operator**[] (size\_t k)  
*Operator [] (Non constant version).*
- T\_ **operator**[] (size\_t k) const  
*Operator [] (Constant version).*
- **Matrix** & **operator**+= (const **Matrix**< T\_ > &m)  
*Operator +=.*
- **Matrix** & **operator**-= (const **Matrix**< T\_ > &m)  
*Operator -=.*
- **Matrix** & **operator**-= (const T\_ &x)  
*Operator -=.*

### 7.5.1 Detailed Description

**template<class T\_>class OFELI::BMatrix< T\_ >**

To handle band matrices.

This class enables storing and manipulating band matrices. The matrix can have different numbers of lower and upper co-diagonals

Template Parameters

---

|           |                                                 |
|-----------|-------------------------------------------------|
| <i>T_</i> | Data type (double, float, complex<double>, ...) |
|-----------|-------------------------------------------------|

## 7.5.2 Constructor & Destructor Documentation

### **BMatrix ( )**

Default constructor.

Initialize a zero dimension band matrix

### **BMatrix ( *size.t size*, *int ld*, *int ud* )**

Constructor that for a band matrix with given size and bandwidth.

Assign 0 to all matrix entries.

Parameters

|           |             |                                            |
|-----------|-------------|--------------------------------------------|
| <i>in</i> | <i>size</i> | Number of rows and columns                 |
| <i>in</i> | <i>ld</i>   | Number of lower co-diagonals (must be > 0) |
| <i>in</i> | <i>ud</i>   | Number of upper co-diagonals (must be > 0) |

## 7.5.3 Member Function Documentation

### **void setSize ( *size.t size*, *int ld*, *int ud* )**

Set size (number of rows) and storage of matrix.

Parameters

|           |             |                                            |
|-----------|-------------|--------------------------------------------|
| <i>in</i> | <i>size</i> | Number of rows and columns                 |
| <i>in</i> | <i>ld</i>   | Number of lower co-diagonals (must be > 0) |
| <i>in</i> | <i>ud</i>   | Number of upper co-diagonals (must be > 0) |

### **void Axy ( *T\_ a*, const BMatrix< T\_ > &*x* )**

Add to matrix the product of a matrix by a scalar.

Parameters

|           |          |                                                                          |
|-----------|----------|--------------------------------------------------------------------------|
| <i>in</i> | <i>a</i> | Scalar to premultiply                                                    |
| <i>in</i> | <i>x</i> | Matrix by which a is multiplied. The result is added to current instance |

### **void Axy ( *T\_ a*, const Matrix< T\_ > \**x* ) [virtual]**

Add to matrix the product of a matrix by a scalar.

Parameters

|           |          |                                                                          |
|-----------|----------|--------------------------------------------------------------------------|
| <i>in</i> | <i>a</i> | Scalar to premultiply                                                    |
| <i>in</i> | <i>x</i> | Matrix by which a is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

### **T\_ operator() ( *size.t i*, *size.t j* ) const [virtual]**

Operator () (Constant version).

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**T\_ & operator() ( size\_t *i*, size\_t *j* )** [virtual]

Operator () (Non constant version).

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**BMatrix< T\_ > & operator= ( const BMatrix< T\_ > & *m* )**

Operator =.

Copy matrix *m* to current matrix instance.

**BMatrix< T\_ > & operator\*= ( const T\_ & *x* )**

Operator \*.

Premultiply matrix entries by constant value *x*

**BMatrix< T\_ > & operator+= ( const T\_ & *x* )**

Operator +.

Add constant *x* to matrix entries.

**int setLU ( )**

Factorize the matrix (LU factorization)

LU factorization of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- 0 if factorization was normally performed,
- *n* if the *n*-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

**int solve ( Vect< T\_ > & *b* )** [virtual]

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

## Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

## Returns

- 0 if solution was normally performed,
- n if the n-th pivot is null.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & *b*, Vect< T\_ > & *x* )**

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

## Parameters

|     |          |                                                              |
|-----|----------|--------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side. |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution         |

## Returns

- 0 if solution was normally performed,
- n if the n-th pivot is null.

**void setDiagonal ( Mesh & *mesh* )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t *k* ) const** [inherited]

Return k-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & *el*, T\_\* *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

## Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_ \* *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                                |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                                   |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                               |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =0, default value). |

**void Prescribe ( int *dof*, int *code*, Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                           |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                        |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( [Vect](#)< T\_ > & *b*, int *flag* = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t *dof*, [Vect](#)< T\_ > & *b*, const [Vect](#)< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                              |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that conatins imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |          |                                                                             |
|--------|----------|-----------------------------------------------------------------------------|
| in,out | <i>b</i> | Vect instance that contains right-hand side on input and solution on output |
|--------|----------|-----------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |          |                                             |
|-----|----------|---------------------------------------------|
| in  | <i>b</i> | Vect instance that contains right-hand side |
| out | <i>x</i> | Vect instance that contains solution        |

Returns

- 0 if solution was normally performed
- *n* if the *n*-th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator () with one argument (Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |          |             |
|----|----------|-------------|
| in | <i>i</i> | entry index |
|----|----------|-------------|

**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |          |             |
|----|----------|-------------|
| in | <i>i</i> | entry index |
|----|----------|-------------|

**T\_& operator[] ( size\_t k )** [inherited]

Operator [] (Non constant version).

Returns *k*-th stored element in matrix Index *k* starts at 0.



**T\_ operator[] ( size\_t k ) const** [inherited]

Operator [] (Constant version).

Returns k-th stored element in matrix Index k starts at 0.

**Matrix& operator+= ( const Matrix< T\_ > & m )** [inherited]

Operator +=.

Add matrix m to current matrix instance.

**Matrix& operator-= ( const Matrix< T\_ > & m )** [inherited]

Operator -=.

Subtract matrix m from current matrix instance.

**Matrix& operator-= ( const T\_ & x )** [inherited]

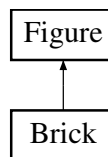
Operator -=.

Subtract constant value x from all matrix entries.

## 7.6 Brick Class Reference

To store and treat a brick (parallelepiped) figure.

Inheritance diagram for Brick:



### Public Member Functions

- **Brick ()**  
*Default constructor.*
- **Brick (const Point< real\_t > &bbm, const Point< real\_t > &bbM, int code=1)**  
*Constructor.*
- **void setBoundingBox (const Point< real\_t > &bbm, const Point< real\_t > &bbM)**  
*Assign bounding box of the brick.*
- **Point< real\_t > getBoundingBox1 () const**  
*Return first point of bounding box (xmin,ymin,zmin)*
- **Point< real\_t > getBoundingBox2 () const**  
*Return second point of bounding box (xmax,ymax,zmax)*
- **real\_t getSignedDistance (const Point< real\_t > &p) const**  
*Return signed distance of a given point from the current brick.*
- **Brick & operator+= (Point< real\_t > a)**  
*Operator +=.*
- **Brick & operator+= (real\_t a)**  
*Operator \*+=.*
- **void setCode (int code)**

Choose a code for the domain defined by the figure.

- void **getSignedDistance** (const **Grid** &g, **Vect**< **real.t** > &d) const  
Calculate signed distance to current figure with respect to grid points.
- **real.t** **dLine** (const **Point**< **real.t** > &p, const **Point**< **real.t** > &a, const **Point**< **real.t** > &b)  
const  
Compute signed distance from a line.

### 7.6.1 Detailed Description

To store and treat a brick (parallelepiped) figure.

### 7.6.2 Constructor & Destructor Documentation

**Brick** ( const **Point**< **real.t** > &*bbm*, const **Point**< **real.t** > &*bbM*, int *code* = 1 )

Constructor.

Parameters

|    |             |                               |
|----|-------------|-------------------------------|
| in | <i>bbm</i>  | first point (xmin,ymin,zmin)  |
| in | <i>bbM</i>  | second point (xmax,ymax,zmax) |
| in | <i>code</i> | Code to assign to rectangle   |

### 7.6.3 Member Function Documentation

**void setBoundingBox** ( const **Point**< **real.t** > &*bbm*, const **Point**< **real.t** > &*bbM* )

Assign bounding box of the brick.

Parameters

|    |            |                               |
|----|------------|-------------------------------|
| in | <i>bbm</i> | first point (xmin,ymin,zmin)  |
| in | <i>bbM</i> | second point (xmax,ymax,zmax) |

**real.t getSignedDistance** ( const **Point**< **real.t** > &*p* ) const [virtual]

Return signed distance of a given point from the current brick.

The computed distance is negative if p lies in the brick, negative if it is outside, and 0 on its boundary

Parameters

|    |          |                                |
|----|----------|--------------------------------|
| in | <i>p</i> | <b>Point</b> <double> instance |
|----|----------|--------------------------------|

Reimplemented from [Figure](#).

**Brick& operator+=** ( **Point**< **real.t** > *a* )

Operator +=.

Translate brick by a vector a

**Brick& operator+=** ( **real.t** *a* )

Operator \*.

Scale brick by a factor a

**void getSignedDistance** ( const **Grid** &*g*, **Vect**< **real.t** > &*d* ) const [inherited]

Calculate signed distance to current figure with respect to grid points.

## Parameters

|    |          |                                                                                                             |
|----|----------|-------------------------------------------------------------------------------------------------------------|
| in | <i>g</i> | <a href="#">Grid</a> instance                                                                               |
| in | <i>d</i> | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

## Remarks

Vector *d* doesn't need to be sized before invoking this function

```
real.t dLine (const Point< real.t > & p, const Point< real.t > & a, const Point< real.t > & b) const [inherited]
```

Compute signed distance from a line.

## Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> for which distance is computed |
| in | <i>a</i> | First vertex of line                                 |
| in | <i>b</i> | Second vertex of line                                |

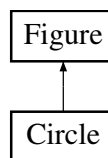
## Returns

Signed distance

## 7.7 Circle Class Reference

To store and treat a circular figure.

Inheritance diagram for Circle:



### Public Member Functions

- [Circle](#) ()  
*Default constructor.*
- [Circle](#) (const [Point](#)< [real.t](#) > &c, [real.t](#) r, int code=1)  
*Constructor.*
- void [setRadius](#) ([real.t](#) r)  
*Assign radius of circle.*
- [real.t](#) [getRadius](#) () const  
*Return radius of circle.*
- void [setCenter](#) (const [Point](#)< [real.t](#) > &c)  
*Assign coordinates of center of circle.*
- [Point](#)< [real.t](#) > [getCenter](#) () const  
*Return coordinates of center of circle.*
- [real.t](#) [getSignedDistance](#) (const [Point](#)< [real.t](#) > &p) const  
*Return signed distance of a given point from the current circle.*

- **Circle** & **operator+=** (**Point**< **real\_t** > a)  
*Operator +=.*
- **Circle** & **operator+=** (**real\_t** a)  
*Operator \*+=.*
- void **setCode** (int code)  
*Choose a code for the domain defined by the figure.*
- void **getSignedDistance** (const **Grid** &g, **Vect**< **real\_t** > &d) const  
*Calculate signed distance to current figure with respect to grid points.*
- **real\_t** **dLine** (const **Point**< **real\_t** > &p, const **Point**< **real\_t** > &a, const **Point**< **real\_t** > &b) const  
*Compute signed distance from a line.*

### 7.7.1 Detailed Description

To store and treat a circular figure.

### 7.7.2 Constructor & Destructor Documentation

**Circle** ( const **Point**< **real\_t** > &c, **real\_t** r, int code = 1 )

Constructor.

Parameters

|    |      |                                                     |
|----|------|-----------------------------------------------------|
| in | c    | Coordinates of center of circle                     |
| in | r    | Radius                                              |
| in | code | Code to assign to the generated domain [Default: 1] |

### 7.7.3 Member Function Documentation

**real\_t** **getSignedDistance** ( const **Point**< **real\_t** > &p ) const [virtual]

Return signed distance of a given point from the current circle.

The computed distance is negative if p lies in the disk, positive if it is outside, and 0 on the circle

Parameters

|    |   |                                |
|----|---|--------------------------------|
| in | p | <b>Point</b> <double> instance |
|----|---|--------------------------------|

Reimplemented from [Figure](#).

**Circle**& **operator+=** ( **Point**< **real\_t** > a )

Operator +=.

Translate circle by a vector a

**Circle**& **operator+=** ( **real\_t** a )

Operator \*+=.

Scale circle by a factor a

void **getSignedDistance** ( const **Grid** &g, **Vect**< **real\_t** > &d ) const [inherited]

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |     |                                                                                                             |
|----|-----|-------------------------------------------------------------------------------------------------------------|
| in | $g$ | <a href="#">Grid</a> instance                                                                               |
| in | $d$ | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector  $d$  doesn't need to be sized before invoking this function

**real\_t dLine ( const Point< real\_t > &  $p$ , const Point< real\_t > &  $a$ , const Point< real\_t > &  $b$  ) const** [inherited]

Compute signed distance from a line.

Parameters

|    |     |                                                      |
|----|-----|------------------------------------------------------|
| in | $p$ | <a href="#">Point</a> for which distance is computed |
| in | $a$ | First vertex of line                                 |
| in | $b$ | Second vertex of line                                |

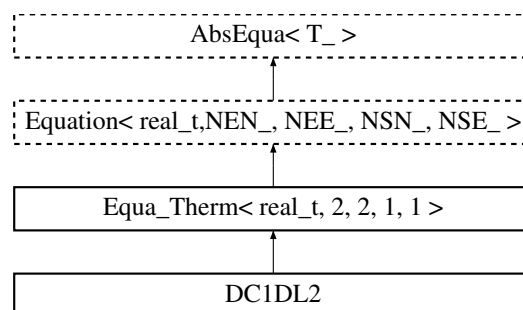
Returns

Signed distance

## 7.8 DC1DL2 Class Reference

Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements.

Inheritance diagram for DC1DL2:



### Public Member Functions

- [DC1DL2](#) ()  
*Default Constructor.*
- [DC1DL2](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [DC1DL2](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor for an element (transient case).*
- [DC1DL2](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time, [real\\_t](#) deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*
- [~DC1DL2](#) ()  
*Destructor.*

- void **build** ()  
*Build the linear system without solving.*
- void **LCapacityToLHS** (real\_t coef=1)  
*Add lumped capacity matrix to left-hand side after multiplying it by coefficient coef*
- void **LCapacityToRHS** (real\_t coef=1)  
*Add lumped capacity contribution to right-hand side after multiplying it by coefficient coef*
- void **LCapacity** (real\_t coef)  
*Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient coef*
- void **CapacityToLHS** (real\_t coef=1)  
*Add Consistent capacity matrix to left-hand side after multiplying it by coefficient coef.*
- void **CapacityToRHS** (real\_t coef=1)  
*Add Consistent capacity contribution to right-hand side after multiplying it by coefficient coef*
- void **Capacity** (real\_t coef=1)  
*Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient coef*
- void **Diffusion** (real\_t coef=1)  
*Add diffusion matrix to left hand side after multiplying it by coefficient coef*
- void **DiffusionToRHS** (real\_t coef=1)  
*Add diffusion contribution to right hand side after multiplying it by coefficient coef*
- void **Convection** (const real\_t &v, real\_t coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **Convection** (const Vect< real\_t > &v, real\_t coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **Convection** (real\_t coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **ConvectionToRHS** (const real\_t &v, real\_t coef=1)  
*Add convection contribution to right-hand side after multiplying it by coefficient coef*
- void **ConvectionToRHS** (real\_t coef=1)  
*Add convection contribution to right-hand side after multiplying it by coefficient coef*
- void **BodyRHS** (UserData< real\_t > &ud, real\_t coef=1)  
*Add body right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BodyRHS** (const Vect< real\_t > &b, int opt=GLOBAL\_ARRAY)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (UserData< real\_t > &ud, real\_t coef=1)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BoundaryRHS** (real\_t flux)  
*Add boundary right-hand side flux to right hand side.*
- void **BoundaryRHS** (const Vect< real\_t > &b, int opt=GLOBAL\_ARRAY)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- real\_t **Flux** () const  
*Return (constant) heat flux in element.*
- void **setInput** (EqDataType opt, Vect< real\_t > &u)  
*Set equation input data.*
- virtual void **setStab** ()  
*Set stabilized formulation.*
- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*

- void `setCapacity` ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void `setDiffusion` ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- void `setConvection` ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void `build` (`TimeStepping` &es)  
*Build the linear system of equations.*
- void `build` (`EigenProblemSolver` &e)  
*Build the linear system for an eigenvalue problem.*
- int `runTransient` ()  
*Run one time step.*
- int `runOneTimeStep` ()  
*Run one time step.*
- int `run` ()  
*Run the equation.*
- void `setRhoCp` (const `real_t` &rhocp)  
*Set product of Density by Specific heat (constants)*
- void `setConductivity` (const `real_t` &diff)  
*Set (constant) thermal conductivity.*
- void `RhoCp` (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void `Conduc` (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void `updateBC` (const `Element` &el, const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `updateBC` (const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `DiagBC` (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void `LocalNodeVector` (`Vect`< T\_ > &b)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be, int dof)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NSE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize `Element` Vector.*
- void `SideVector` (const `Vect`< T\_ > &b)  
*Localize `Side` Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*

- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*



- void **AxbAssembly** (const **Side** &sd, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- void **setInitialSolution** (const **Vect**< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t **setMaterialProperty** (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void **setMesh** (**Mesh** &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- **Mesh** & **getMesh** () const  
*Return reference to **Mesh** instance.*
- **LinearSolver**< T\_ > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int **SolveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_, NEE\_ > **eMat**  
***LocalMatrix** instance containing local matrix associated to current element.*
- **LocalMatrix**< T\_, NSE\_, NSE\_ > **sMat**  
***LocalMatrix** instance containing local matrix associated to current side.*
- **LocalVect**< T\_, NEE\_ > **ePrev**  
***LocalVect** instance containing local vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRHS**  
***LocalVect** instance containing local right-hand side vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRes**  
***LocalVect** instance containing local residual vector associated to current element.*
- **LocalVect**< T\_, NSE\_ > **sRHS**  
***LocalVect** instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.8.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements.

Note that members calculating element arrays have as an argument a real `coef` that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.8.2 Constructor & Destructor Documentation

#### DC1DL2 ( )

Default Constructor.

Constructs an empty equation.

#### DC1DL2 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time* = 0. )

Constructor for an element (transient case).

Parameters

|             |                                                                                 |
|-------------|---------------------------------------------------------------------------------|
| <i>el</i>   | [in] Pointer to element                                                         |
| <i>u</i>    | [in] <a href="#">Vect</a> instance that contains solution at previous time step |
| <i>time</i> | [in] Current time value (Default value is 0)                                    |

#### DC1DL2 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                   |
|----|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>     | Pointer to element.                                                                                                                                                                                                               |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                       |
| in | <i>time</i>   | Current time value (Default value is 0).                                                                                                                                                                                          |
| in | <i>deltat</i> | Value of time step                                                                                                                                                                                                                |
| in | <i>scheme</i> | Time Integration Scheme: <ul style="list-style-type: none"> <li>• FORWARD_EULER for Forward Euler scheme</li> <li>• BACKWARD_EULER for Backward Euler scheme</li> <li>• CRANK_NICOLSON for Crank-Nicolson Euler scheme</li> </ul> |

### 7.8.3 Member Function Documentation

#### void LCapacityToLHS ( real.t *coef* = 1 ) [virtual]

Add lumped capacity matrix to left-hand side after multiplying it by coefficient `coef`

Parameters

|    |             |                                                    |
|----|-------------|----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|----|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

#### void LCapacityToRHS ( real.t *coef* = 1 ) [virtual]

Add lumped capacity contribution to right-hand side after multiplying it by coefficient `coef`

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void LCapacity ( real.t coef )**

Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

**void CapacityToLHS ( real.t coef = 1 ) [virtual]**

Add Consistent capacity matrix to left-hand side after multiplying it by coefficient *coef*.

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void CapacityToRHS ( real.t coef = 1 ) [virtual]**

Add Consistent capacity contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void Capacity ( real.t coef = 1 )**

Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

**void Diffusion ( real.t coef = 1 ) [virtual]**

Add diffusion matrix to left hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void DiffusionToRHS ( real.t coef = 1 ) [virtual]**

Add diffusion contribution to right hand side after multiplying it by coefficient *coef*

To be used for explicit diffusion term

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void Convection ( const real.t & v, real.t coef = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>v</i>    | Constant velocity vector                           |
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |

**void Convection ( const Vect< real.t > & v, real.t coef = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*

Case where velocity field is given by a vector *v*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>v</i>    | Velocity vector                                    |
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |

**void Convection ( real.t coef = 1 ) [virtual]**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*

Case where velocity field has been previously defined

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void ConvectionToRHS ( const real.t & v, real.t coef = 1 )**

Add convection contribution to right-hand side after multiplying it by coefficient *coef*

To be used for explicit convection term.

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>v</i>    | Velocity vector                                    |
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |

**void ConvectionToRHS ( real.t coef = 1 ) [virtual]**

Add convection contribution to right-hand side after multiplying it by coefficient *coef*

Case where velocity field has been previously defined

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void BodyRHS ( UserData< real.t > & ud, real.t coef = 1 )**

Add body right-hand side term to right hand side after multiplying it by coefficient *coef*

Parameters

|    |             |                                                                                                                   |
|----|-------------|-------------------------------------------------------------------------------------------------------------------|
| in | <i>ud</i>   | Instance of <a href="#">UserData</a> or of a derived class. Contains a member function that provides body source. |
| in | <i>coef</i> | Coefficient to multiply by added term [default: 1]                                                                |

**void BodyRHS ( const Vect< real.t > & b, int opt = GLOBAL\_ARRAY )** [virtual]

Add body right-hand side term to right hand side.

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Vector containing source at element nodes.                                                                              |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void BoundaryRHS ( UserData< real.t > & ud, real.t coef = 1 )**

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |             |                                                                                                                      |
|----|-------------|----------------------------------------------------------------------------------------------------------------------|
| in | <i>ud</i>   | Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source. |
| in | <i>coef</i> | Coefficient to multiply by added term [default: 1]                                                                   |

**void BoundaryRHS ( real.t flux )**

Add boundary right-hand side flux to right hand side.

Parameters

|    |             |                                         |
|----|-------------|-----------------------------------------|
| in | <i>flux</i> | Vector containing source at side nodes. |
|----|-------------|-----------------------------------------|

**void BoundaryRHS ( const Vect< real.t > & b, int opt = GLOBAL\_ARRAY )** [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Vector containing source at side nodes.                                                                                 |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 2, 2, 1, 1 >](#).

**void setInput ( EqDataType opt, Vect< real.t > & u )**

Set equation input data.

## Parameters

|           |            |                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|-----------|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>opt</i> | Parameter that selects data type for input. This parameter is to be chosen in the enumerated variable EqDataType <ul style="list-style-type: none"> <li>• INITIAL_FIELD: Initial temperature</li> <li>• BOUNDARY_CONDITION_DATA: Boundary condition (Dirichlet)</li> <li>• SOURCE_DATA: Heat source</li> <li>• FLUX_DATA: Heat flux (Neumann boundary condition)</li> <li>• VELOCITY: Velocity vector (for the convection term)</li> </ul> |
| <b>in</b> | <i>u</i>   | Vector containing input data                                                                                                                                                                                                                                                                                                                                                                                                               |

**virtual void setStab ( )** [virtual], [inherited]

Set stabilized formulation.

Stabilized variational formulations are to be used when the Peclet number is large.  
By default, no stabilization is used.

**void build ( TimeStepping & s )** [inherited]

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

## Parameters

|           |          |                                         |
|-----------|----------|-----------------------------------------|
| <b>in</b> | <i>s</i> | Reference to used TimeStepping instance |
|-----------|----------|-----------------------------------------|

**void build ( EigenProblemSolver & e )** [inherited]

Build the linear system for an eigenvalue problem.

## Parameters

|           |          |                                               |
|-----------|----------|-----------------------------------------------|
| <b>in</b> | <i>e</i> | Reference to used EigenProblemSolver instance |
|-----------|----------|-----------------------------------------------|

**int runTransient ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is to be used only if a *TRANSIENT* analysis is required.

## Returns

Return error from the linear system solver

**int runOneTimeStep ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is identical to the function run-Transient.

Returns

Return error from the linear system solver

**int run ( )** [inherited]

Run the equation.

If the analysis (see function setAnalysis) is STEADY\_STATE, then the function solves the stationary equation.

If the analysis is TRANSIENT, then the function performs time stepping until the final time is reached.

**void updateBC ( const Element & el, const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |    |                                                 |
|----|----|-------------------------------------------------|
| in | el | Reference to current element instance           |
| in | bc | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |    |                                                 |
|----|----|-------------------------------------------------|
| in | bc | Vector that contains imposed values at all DOFs |
|----|----|-------------------------------------------------|

Remarks

The current element is pointed by \_theElement

**void DiagBC ( int dof.type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |          |                                                                                                                                                                                                                                                                           |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | dof.type | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | dof      | DOF setting: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF No. dof is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.



## Parameters

|    |          |                                                                                                                                                                                                          |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute ePrev. This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be*, int *dof* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer *\_theSide*

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array *\_x[0]*, *\_x[1]*, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real\\_t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix< T\\_ > \\* A](#) )** [inherited]

Assemble element matrix into global one.

Parameters

|                   |                                                                                                                                                   |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <a href="#">A</a> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix< T\\_ > & A](#) )** [inherited]

Assemble element matrix into global one.

Parameters

|                   |                            |
|-------------------|----------------------------|
| <a href="#">A</a> | Reference to global matrix |
|-------------------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect< T\\_ > & b](#) )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|                   |                                            |
|-------------------|--------------------------------------------|
| <a href="#">b</a> | Reference to global right-hand side vector |
|-------------------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix< T\\_ > & A](#) )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

## Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|



|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | pc | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul> |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |   |                                                                                 |
|--------|---|---------------------------------------------------------------------------------|
| in     | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | b | Vector containing right-hand side                                               |
| in,out | x | Vector containing initial guess of solution on input, actual solution on output |

## 7.8.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

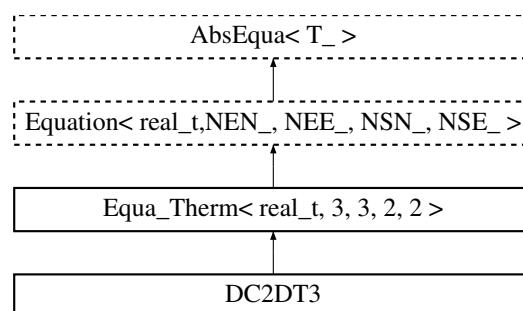
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.9 DC2DT3 Class Reference

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

Inheritance diagram for DC2DT3:



## Public Member Functions

- [DC2DT3](#) ()  
*Default Constructor. Constructs an empty equation.*
- [DC2DT3](#) ([Mesh](#) &ms)  
*Constructor using [Mesh](#) data.*

- **DC2DT3** (**Mesh** &ms, **Vect**< **real\_t** > &u)  
*Constructor using **Mesh** and initial condition.*
- **DC2DT3** (const **Element** \*el)  
*Constructor for an element.*
- **DC2DT3** (const **Side** \*sd)  
*Constructor for a boundary side.*
- **DC2DT3** (const **Element** \*el, const **Vect**< **real\_t** > &u, **real\_t** time=0.)  
*Constructor for an element (transient case).*
- **DC2DT3** (const **Element** \*el, const **Vect**< **real\_t** > &u, **real\_t** time, **real\_t** deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*
- **DC2DT3** (const **Side** \*sd, const **Vect**< **real\_t** > &u, **real\_t** time=0.)  
*Constructor for a boundary side (transient case).*
- **DC2DT3** (const **Side** \*sd, const **Vect**< **real\_t** > &u, **real\_t** time, **real\_t** deltat, int scheme)  
*Constructor for a side (transient case) with specification of time integration scheme.*
- **~DC2DT3** ()  
*Destructor.*
- void **LCapacityToLHS** (**real\_t** coef=1)  
*Add lumped capacity matrix to left-hand side after multiplying it by coefficient **coef***
- void **LCapacityToRHS** (**real\_t** coef=1)  
*Add lumped capacity contribution to right-hand side after multiplying it by coefficient **coef***
- void **LCapacity** (**real\_t** coef)  
*Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient **coef***
- void **CapacityToLHS** (**real\_t** coef=1)  
*Add Consistent capacity matrix to left-hand side after multiplying it by coefficient **coef***
- void **CapacityToRHS** (**real\_t** coef=1)  
*Add Consistent capacity contribution to right-hand side after multiplying it by coefficient **coef***
- void **Capacity** (**real\_t** coef=1)  
*Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient **coef***
- void **Diffusion** (**real\_t** coef=1)  
*Add diffusion matrix to left-hand side after multiplying it by coefficient **coef***
- void **Diffusion** (const **LocalMatrix**< **real\_t**, 2, 2 > &diff, **real\_t** coef=1)  
*Add diffusion matrix to left-hand side after multiplying it by coefficient **coef***
- void **DiffusionToRHS** (**real\_t** coef=1)  
*Add diffusion contribution to right-hand side after multiplying it by coefficient **coef** To be used for explicit diffusion term.*
- void **Convection** (const **Point**< **real\_t** > &v, **real\_t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient **coef***
- void **Convection** (const **Vect**< **real\_t** > &v, **real\_t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient **coef***
- void **Convection** (**real\_t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient **coef***
- void **ConvectionToRHS** (const **Point**< **real\_t** > &v, **real\_t** coef=1)  
*Add convection contribution to right-hand side after multiplying it by coefficient **coef***
- void **ConvectionToRHS** (**real\_t** coef=1)  
*Add convection contribution to right-hand side after multiplying it by coefficient **coef***
- void **LinearExchange** (**real\_t** coef, **real\_t** T)  
*Add an edge linear exchange term to left and right-hand sides.*

- void **BodyRHS** (**UserData**< **real\_t** > &ud, **real\_t** coef=1)  
*Add body right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BodyRHS** (const **Vect**< **real\_t** > &bf, int opt=**GLOBAL\_ARRAY**)  
*Add body right-hand side term to right hand side.*
- void **BodyRHS** (**real\_t** bf)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (**UserData**< **real\_t** > &ud, **real\_t** coef=1)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BoundaryRHS** (**real\_t** flux)  
*Add boundary right-hand side flux to right hand side.*
- void **BoundaryRHS** (const **Vect**< **real\_t** > &b, int opt=**GLOBAL\_ARRAY**)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- void **Periodic** (**real\_t** coef=1.e20)  
*Add contribution of periodic boundary condition (by a penalty technique).*
- **Point**< **real\_t** > & **Flux** () const  
*Return (constant) heat flux in element.*
- **Point**< **real\_t** > & **Grad** (const **LocalVect**< **real\_t**, 3 > &u) const  
*Return gradient of a vector in element.*
- **Point**< **real\_t** > & **Grad** (const **Vect**< **real\_t** > &u) const  
*Return gradient of a vector in element.*
- void **setInput** (**EqDataType** opt, **Vect**< **real\_t** > &u)  
*Set equation input data.*
- void **JouleHeating** (const **Vect**< **real\_t** > &sigma, const **Vect**< **real\_t** > &psi)  
*Set Joule heating term as source.*
- void **build** ()  
*Build the linear system of equations.*
- virtual void **setStab** ()  
*Set stabilized formulation.*
- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setCapacity** ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setDiffusion** ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- void **setConvection** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **build** (**EigenProblemSolver** &e)  
*Build the linear system for an eigenvalue problem.*
- int **runTransient** ()  
*Run one time step.*
- int **runOneTimeStep** ()  
*Run one time step.*
- int **run** ()  
*Run the equation.*
- void **setRhoCp** (const **real\_t** &rhocp)  
*Set product of Density by Specific heat (constants)*

- void **setConductivity** (const **real\_t** &diff)  
*Set (constant) thermal conductivity.*
- void **RhoCp** (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void **Conduc** (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*

- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > [eMat](#)  
*LocalMatrix* instance containing local matrix associated to current element.
- [LocalMatrix](#)< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > [sMat](#)  
*LocalMatrix* instance containing local matrix associated to current side.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [ePrev](#)  
*LocalVect* instance containing local vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRes](#)  
*LocalVect* instance containing local residual vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NSE<sub>-</sub> > [sRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void [set](#) (const [Element](#) \*el)  
*Run the equation.*
- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.9.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

Note that members calculating element arrays have as an argument a real coef that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.9.2 Constructor & Destructor Documentation

DC2DT3 ( [Mesh](#) & *ms* )

Constructor using [Mesh](#) data.

Parameters

|                    |           |                               |
|--------------------|-----------|-------------------------------|
| <a href="#">in</a> | <i>ms</i> | <a href="#">Mesh</a> instance |
|--------------------|-----------|-------------------------------|

DC2DT3 ( [Mesh](#) & *ms*, [Vect](#)< real\_t > & *u* )

Constructor using [Mesh](#) and initial condition.

Parameters

|    |           |                                                           |
|----|-----------|-----------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance                             |
| in | <i>u</i>  | <a href="#">Vect</a> instance containing initial solution |

### DC2DT3 ( const Element \* *el* )

Constructor for an element.

Parameters

|           |                                             |
|-----------|---------------------------------------------|
| <i>el</i> | Pointer to <a href="#">Element</a> instance |
|-----------|---------------------------------------------|

### DC2DT3 ( const Side \* *sd* )

Constructor for a boundary side.

Parameters

|    |           |                                          |
|----|-----------|------------------------------------------|
| in | <i>sd</i> | Pointer to <a href="#">Side</a> instance |
|----|-----------|------------------------------------------|

### DC2DT3 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time* = 0. )

Constructor for an element (transient case).

Parameters

|    |             |                                                                            |
|----|-------------|----------------------------------------------------------------------------|
| in | <i>el</i>   | Pointer to element                                                         |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step |
| in | <i>time</i> | Current time value [Default: 0]                                            |

### DC2DT3 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                   |
|----|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>     | Pointer to element.                                                                                                                                                                                                               |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                       |
| in | <i>time</i>   | Current time value [Default: 0].                                                                                                                                                                                                  |
| in | <i>deltat</i> | Value of time step.                                                                                                                                                                                                               |
| in | <i>scheme</i> | Time Integration Scheme: <ul style="list-style-type: none"> <li>• FORWARD_EULER for Forward Euler scheme</li> <li>• BACKWARD_EULER for Backward Euler scheme</li> <li>• CRANK_NICOLSON for Crank-Nicolson Euler scheme</li> </ul> |

### DC2DT3 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time* = 0. )

Constructor for a boundary side (transient case).

Parameters

|    |             |                                                                             |
|----|-------------|-----------------------------------------------------------------------------|
| in | <i>sd</i>   | Pointer to side.                                                            |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | <i>time</i> | Current time value [Default: 0]                                             |

**DC2DT3 ( const Side \* *sd*, const Vect< real\_t > &*u*, real\_t *time*, real\_t *deltat*, int *scheme* )**

Constructor for a side (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                   |
|----|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i>     | Pointer to side.                                                                                                                                                                                                                  |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                       |
| in | <i>time</i>   | Current time value [Default: 0].                                                                                                                                                                                                  |
| in | <i>deltat</i> | Value of time step.                                                                                                                                                                                                               |
| in | <i>scheme</i> | Time Integration Scheme: <ul style="list-style-type: none"> <li>• FORWARD_EULER for Forward Euler scheme</li> <li>• BACKWARD_EULER for Backward Euler scheme</li> <li>• CRANK_NICOLSON for Crank-Nicolson Euler scheme</li> </ul> |

### 7.9.3 Member Function Documentation

**void LCapacityToLHS ( real\_t *coef* = 1 ) [virtual]**

Add lumped capacity matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real\\_t, 3, 3, 2, 2 >](#).

**void LCapacityToRHS ( real\_t *coef* = 1 ) [virtual]**

Add lumped capacity contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real\\_t, 3, 3, 2, 2 >](#).

**void LCapacity ( real\_t *coef* )**

Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*

Parameters

|    |             |                                                    |
|----|-------------|----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|----|-------------|----------------------------------------------------|

**void CapacityToLHS ( real\_t *coef* = 1 ) [virtual]**

Add Consistent capacity matrix to left-hand side after multiplying it by coefficient *coef*



Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void CapacityToRHS ( real.t coef = 1 )** [virtual]

Add Consistent capacity contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Capacity ( real.t coef = 1 )**

Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

**void Diffusion ( real.t coef = 1 )** [virtual]

Add diffusion matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Diffusion ( const LocalMatrix< real.t, 2, 2 > & diff, real.t coef = 1 )**

Add diffusion matrix to left-hand side after multiplying it by coefficient *coef*

Case where the diffusivity matrix is given as an argument.

Parameters

|           |             |                                                        |
|-----------|-------------|--------------------------------------------------------|
| <i>in</i> | <i>diff</i> | Diffusion matrix (class <a href="#">LocalMatrix</a> ). |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]     |

**void DiffusionToRHS ( real.t coef = 1 )** [virtual]

Add diffusion contribution to right-hand side after multiplying it by coefficient *coef* To be used for explicit diffusion term.

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Convection ( const Point< real.t > & v, real.t coef = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|    |        |                                                    |
|----|--------|----------------------------------------------------|
| in | $v$    | Constant velocity vector                           |
| in | $coef$ | Coefficient to multiply by added term [Default: 1] |

**void Convection ( const Vect< real.t > &  $v$ , real.t  $coef = 1$  )**

Add convection matrix to left-hand side after multiplying it by coefficient  $coef$

Case where velocity field is given by a vector  $v$

Parameters

|    |        |                                                    |
|----|--------|----------------------------------------------------|
| in | $v$    | Velocity vector                                    |
| in | $coef$ | Coefficient to multiply by added term (Default: 1) |

**void Convection ( real.t  $coef = 1$  )** [virtual]

Add convection matrix to left-hand side after multiplying it by coefficient  $coef$

Case where velocity field has been previously defined

Parameters

|    |        |                                                    |
|----|--------|----------------------------------------------------|
| in | $coef$ | Coefficient to multiply by added term [Default: 1] |
|----|--------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void ConvectionToRHS ( const Point< real.t > &  $v$ , real.t  $coef = 1$  )**

Add convection contribution to right-hand side after multiplying it by coefficient  $coef$

To be used for explicit convection term.

Parameters

|    |        |                                                    |
|----|--------|----------------------------------------------------|
| in | $v$    | Velocity vector                                    |
| in | $coef$ | Coefficient to multiply by added term [Default: 1] |

**void ConvectionToRHS ( real.t  $coef = 1$  )** [virtual]

Add convection contribution to right-hand side after multiplying it by coefficient  $coef$

Case where velocity field has been previously defined

Parameters

|    |        |                                                    |
|----|--------|----------------------------------------------------|
| in | $coef$ | Coefficient to multiply by added term [Default: 1] |
|----|--------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void LinearExchange ( real.t  $coef$ , real.t  $T$  )**

Add an edge linear exchange term to left and right-hand sides.

Parameters

|    |        |                             |
|----|--------|-----------------------------|
| in | $coef$ | Coefficient of exchange     |
| in | $T$    | External value for exchange |

Remarks

This assumes a constant value of  $T$

**void BodyRHS ( UserData< real\_t > & *ud*, real\_t *coef* = 1 )**

Add body right-hand side term to right hand side after multiplying it by coefficient *coef*

Parameters

|    |             |                                                                                                                   |
|----|-------------|-------------------------------------------------------------------------------------------------------------------|
| in | <i>ud</i>   | Instance of <a href="#">UserData</a> or of a derived class. Contains a member function that provides body source. |
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]                                                                |

**void BodyRHS ( const Vect< real.t > &bf, int opt = GLOBAL\_ARRAY )** [virtual]

Add body right-hand side term to right hand side.

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>bf</i>  | Vector containing source at element nodes.                                                                              |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void BodyRHS ( real.t bf )**

Add body right-hand side term to right hand side.

Case where the body right-hand side is piecewise constant.

Parameters

|    |           |                                                |
|----|-----------|------------------------------------------------|
| in | <i>bf</i> | Value of thermal source (Constant in element). |
|----|-----------|------------------------------------------------|

**void BoundaryRHS ( UserData< real.t > &ud, real.t coef = 1 )**

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |             |                                                                                                                      |
|----|-------------|----------------------------------------------------------------------------------------------------------------------|
| in | <i>ud</i>   | Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source. |
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]                                                                   |

**void BoundaryRHS ( real.t flux )**

Add boundary right-hand side flux to right hand side.

Parameters

|    |             |                                         |
|----|-------------|-----------------------------------------|
| in | <i>flux</i> | Vector containing source at side nodes. |
|----|-------------|-----------------------------------------|

**void BoundaryRHS ( const Vect< real.t > &b, int opt = GLOBAL\_ARRAY )** [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Vector containing source at side nodes                                                                                  |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 2 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Periodic ( real\_t coef = 1.e20 )**

Add contribution of periodic boundary condition (by a penalty technique).

Boundary nodes where periodic boundary conditions are to be imposed must have codes equal to PERIODIC.A on one side and PERIODIC.B on the opposite side.

Parameters

|    |      |                                             |
|----|------|---------------------------------------------|
| in | coef | Value of penalty parameter [Default: 1.e20] |
|----|------|---------------------------------------------|

**Point<real\_t>& Grad ( const LocalVect< real\_t, 3 > & u ) const**

Return gradient of a vector in element.

Parameters

|    |   |                                        |
|----|---|----------------------------------------|
| in | u | Vector for which gradient is computed. |
|----|---|----------------------------------------|

**Point<real\_t>& Grad ( const Vect< real\_t > & u ) const**

Return gradient of a vector in element.

Parameters

|    |   |                                                                                              |
|----|---|----------------------------------------------------------------------------------------------|
| in | u | Global vector for which gradient is computed. Vector u has as size the total number of nodes |
|----|---|----------------------------------------------------------------------------------------------|

**void setInput ( EqDataType opt, Vect< real\_t > & u )**

Set equation input data.

Parameters

|    |     |                                                                                                                                                                                                                                                                                                                                                                             |
|----|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | opt | Parameter to select type of input (enumerated values) <ul style="list-style-type: none"> <li>INITIAL_FIELD: Initial temperature</li> <li>BOUNDARY_CONDITION_DATA: Boundary condition (Dirichlet)</li> <li>SOURCE_DATA: Heat source</li> <li>FLUX_DATA: Heat flux (Neumann boundary condition)</li> <li>VELOCITY_FIELD: Velocity vector (for the convection term)</li> </ul> |
| in | u   | Vector containing input data                                                                                                                                                                                                                                                                                                                                                |

**void JouleHeating ( const Vect< real\_t > & sigma, const Vect< real\_t > & psi )**

Set Joule heating term as source.

Parameters

|    |       |                                                                              |
|----|-------|------------------------------------------------------------------------------|
| in | sigma | <a href="#">Vect</a> instance containing electric conductivity (elementwise) |
| in | psi   | <a href="#">Vect</a> instance containing electric potential (elementwise)    |

**void build ( )**

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

**void set ( const Element \* *el* )** [protected]

Run the equation.

If the analysis (see function setAnalysis) is STEADY\_STATE, then the function solves the stationary equation.

If the analysis is TRANSIENT, then the function performs time stepping until the final time is reached.

**virtual void setStab ( )** [virtual], [inherited]

Set stabilized formulation.

Stabilized variational formulations are to be used when the Pclet number is large.

By default, no stabilization is used.

**void build ( EigenProblemSolver & *e* )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |          |                                               |
|----|----------|-----------------------------------------------|
| in | <i>e</i> | Reference to used EigenProblemSolver instance |
|----|----------|-----------------------------------------------|

**int runTransient ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is to be used only if a TRANSIENT analysis is required.

Returns

Return error from the linear system solver

**int runOneTimeStep ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is identical to the function runTransient.

Returns

Return error from the linear system solver

**int run ( )** [inherited]

Run the equation.

If the analysis (see function setAnalysis) is STEADY\_STATE, then the function solves the stationary equation.

If the analysis is TRANSIENT, then the function performs time stepping until the final time is reached.

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

## Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |



## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

## Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |



**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

### 7.9.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

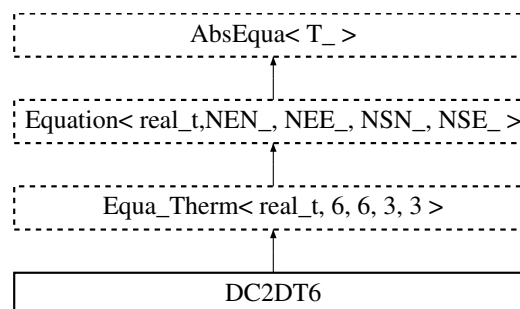
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.10 DC2DT6 Class Reference

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles.

Inheritance diagram for DC2DT6:



### Public Member Functions

- [DC2DT6](#) ()  
*Default Constructor.*
- [DC2DT6](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [DC2DT6](#) (const [Side](#) \*sd)  
*Constructor for a boundary side.*
- [DC2DT6](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor for an element (Transient case).*
- [DC2DT6](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time, [real\\_t](#) deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*
- [DC2DT6](#) (const [Side](#) \*sd, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor for a boundary side (transient case).*

- **DC2DT6** (const **Side** \*sd, const **Vect**< **real.t** > &u, **real.t** time, **real.t** deltat, int scheme)  
*Constructor for a side (transient case) with specification of time integration scheme.*
- **~DC2DT6** ()  
*Destructor.*
- void **Diffusion** (**real.t** coef=1)  
*Add diffusion matrix to left hand side after multiplying it by coefficient coef*
- void **Convection** (**real.t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **Convection** (**Point**< **real.t** > &v, **real.t** coef=1)  
*Add convection matrix to left hand side after multiplying it by coefficient coef*
- void **Convection** (const **Vect**< **real.t** > &v, **real.t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **BodyRHS** (const **Vect**< **real.t** > &b, int opt=**GLOBAL\_ARRAY**)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (const **Vect**< **real.t** > &sf, int opt=**GLOBAL\_ARRAY**)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- virtual void **setStab** ()  
*Set stabilized formulation.*
- virtual void **LCapacityToLHS** (**real.t** coef=1)  
*Add lumped capacity contribution to left-hand side.*
- virtual void **LCapacityToRHS** (**real.t** coef=1)  
*Add lumped capacity contribution to right-hand side.*
- virtual void **CapacityToLHS** (**real.t** coef=1)  
*Add consistent capacity contribution to left-hand side.*
- virtual void **CapacityToRHS** (**real.t** coef=1)  
*Add consistent capacity contribution to right-hand side.*
- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setCapacity** ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void **DiffusionToRHS** (**real.t** coef=1.)  
*Add diffusion term to right-hand side.*
- void **setDiffusion** ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- virtual void **ConvectionToRHS** (**real.t** coef=1.)  
*Add convection term to right-hand side.*
- void **setConvection** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **build** ()  
*Build the linear system of equations.*
- void **build** (**TimeStepping** &ts)  
*Build the linear system of equations.*
- void **build** (**EigenProblemSolver** &e)  
*Build the linear system for an eigenvalue problem.*
- int **runTransient** ()  
*Run one time step.*

- int `runOneTimeStep` ()  
*Run one time step.*
- int `run` ()  
*Run the equation.*
- void `setRhoCp` (const `real_t` &rhocp)  
*Set product of Density by Specific heat (constants)*
- void `setConductivity` (const `real_t` &diff)  
*Set (constant) thermal conductivity.*
- void `RhoCp` (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void `Conduc` (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void `updateBC` (const `Element` &el, const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `updateBC` (const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `DiagBC` (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void `LocalNodeVector` (`Vect`< T\_ > &b)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be, int dof)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NSE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize `Element` Vector.*
- void `SideVector` (const `Vect`< T\_ > &b)  
*Localize `Side` Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()  
*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix`< T\_ > \*A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScVect`< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix`< T\_ > &A)  
*Assemble element matrix into global one.*

- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- [size\\_t](#) [getNbNodes](#) () const  
*Return number of element nodes.*
- [size\\_t](#) [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*

- `Mesh` & `getMesh` () const  
*Return reference to `Mesh` instance.*
- `LinearSolver< T_ > &getLinearSolver` ()  
*Return reference to linear solver instance.*
- void `setSolver` (`Iteration` ls, `Preconditioner` pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int `SolveLinearSystem` (`Matrix`< T\_ > \*A, `Vect`< T\_ > &b, `Vect`< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- `LocalMatrix`< T\_, NEE\_, NEE\_ > `eMat`  
*`LocalMatrix` instance containing local matrix associated to current element.*
- `LocalMatrix`< T\_, NSE\_, NSE\_ > `sMat`  
*`LocalMatrix` instance containing local matrix associated to current side.*
- `LocalVect`< T\_, NEE\_ > `ePrev`  
*`LocalVect` instance containing local vector associated to current element.*
- `LocalVect`< T\_, NEE\_ > `eRHS`  
*`LocalVect` instance containing local right-hand side vector associated to current element.*
- `LocalVect`< T\_, NEE\_ > `eRes`  
*`LocalVect` instance containing local residual vector associated to current element.*
- `LocalVect`< T\_, NSE\_ > `sRHS`  
*`LocalVect` instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void `setMaterial` ()  
*Set material properties.*
- void `Init` (const `Element` \*el)  
*Set element arrays to zero.*
- void `Init` (const `Side` \*sd)  
*Set side arrays to zero.*

### 7.10.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles.

Note that members calculating element arrays have as an argument a real coef that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.10.2 Constructor & Destructor Documentation

#### DC2DT6 ( )

Default Constructor.

Constructs an empty equation.

#### DC2DT6 ( const `Element` \* el )

Constructor for an element.

Parameters

|           |           |                     |
|-----------|-----------|---------------------|
| <b>in</b> | <i>el</i> | Pointer to element. |
|-----------|-----------|---------------------|

**DC2DT6 ( const Side \* *sd* )**

Constructor for a boundary side.

Parameters

|           |           |                  |
|-----------|-----------|------------------|
| <b>in</b> | <i>sd</i> | Pointer to side. |
|-----------|-----------|------------------|

**DC2DT6 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time* = 0. )**

Constructor for an element (Transient case).

Parameters

|           |             |                                                                             |
|-----------|-------------|-----------------------------------------------------------------------------|
| <b>in</b> | <i>el</i>   | Pointer to element.                                                         |
| <b>in</b> | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| <b>in</b> | <i>time</i> | Current time value [Default: 0].                                            |

**DC2DT6 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|           |               |                                                                                                                                                                                                                            |
|-----------|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>el</i>     | Pointer to element.                                                                                                                                                                                                        |
| <b>in</b> | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                |
| <b>in</b> | <i>time</i>   | Current time value [Default: 1]                                                                                                                                                                                            |
| <b>in</b> | <i>deltat</i> | Value of time step                                                                                                                                                                                                         |
| <b>in</b> | <i>scheme</i> | Time Integration Scheme: <ul style="list-style-type: none"> <li>• FORWARD_EULER: Forward Euler scheme</li> <li>• BACKWARD_EULER: Backward Euler scheme,</li> <li>• CRANK_NICOLSON: Crank-Nicolson Euler scheme.</li> </ul> |

**DC2DT6 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time* = 0. )**

Constructor for a boundary side (transient case).

Parameters

|           |             |                                                                             |
|-----------|-------------|-----------------------------------------------------------------------------|
| <b>in</b> | <i>sd</i>   | Pointer to side.                                                            |
| <b>in</b> | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| <b>in</b> | <i>time</i> | Current time value [Default: 0].                                            |

**DC2DT6 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for a side (transient case) with specification of time integration scheme.

## Parameters

|    |               |                                                                                                                                                                                                                                                                      |
|----|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i>     | Pointer to side.                                                                                                                                                                                                                                                     |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                                                          |
| in | <i>time</i>   | Current time value                                                                                                                                                                                                                                                   |
| in | <i>deltat</i> | Value of time step                                                                                                                                                                                                                                                   |
| in | <i>scheme</i> | Time Integration Scheme: To be chosen among the enumerated values: <ul style="list-style-type: none"> <li>• FORWARD_EULER: Forward Euler scheme</li> <li>• BACKWARD_EULER: Backward Euler scheme,</li> <li>• CRANK_NICOLSON: Crank-Nicolson Euler scheme.</li> </ul> |

**7.10.3 Member Function Documentation**

**void Diffusion ( real\_t coef = 1 )** [virtual]

Add diffusion matrix to left hand side after multiplying it by coefficient coef

## Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 6, 6, 3, 3 >](#).

**void Convection ( real\_t coef = 1 )** [virtual]

Add convection matrix to left-hand side after multiplying it by coefficient coef

Case where velocity field has been previously defined

## Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 6, 6, 3, 3 >](#).

**void Convection ( Point< real\_t > & v, real\_t coef = 1 )**

Add convection matrix to left hand side after multiplying it by coefficient coef

## Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>v</i>    | Constant velocity vector.                           |
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void Convection ( const Vect< real\_t > & v, real\_t coef = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient coef

Case where velocity field is given by a vector v

## Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>v</i>    | Velocity vector.                                    |
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void BodyRHS ( const Vect< real\_t > & b, int opt = GLOBAL\_ARRAY )** [virtual]

Add body right-hand side term to right hand side.

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Local vector (of size 6) containing source at element nodes                                                             |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 6 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa\\_Therm< real\\_t, 6, 6, 3, 3 >](#).

**void BoundaryRHS ( const Vect< real\_t > &sf, int opt = GLOBAL\_ARRAY )** [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>sf</i>  | Vector containing source at side nodes                                                                                  |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa\\_Therm< real\\_t, 6, 6, 3, 3 >](#).

**virtual void setStab ( )** [virtual], [inherited]

Set stabilized formulation.

Stabilized variational formulations are to be used when the Pclet number is large.

By default, no stabilization is used.

**virtual void LCapacityToLHS ( real\_t coef = 1 )** [virtual], [inherited]

Add lumped capacity contribution to left-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the matrix before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|

**virtual void LCapacityToRHS ( real\_t coef = 1 )** [virtual], [inherited]

Add lumped capacity contribution to right-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the vector before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|

**virtual void CapacityToLHS ( real\_t coef = 1 )** [virtual], [inherited]

Add consistent capacity contribution to left-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the matrix before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|

**virtual void CapacityToRHS ( real\_t coef = 1 )** [virtual], [inherited]

Add consistent capacity contribution to right-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the vector before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|



**void build ( )** [inherited]

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

**void build ( TimeStepping & s )** [inherited]

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

Parameters

|           |          |                                         |
|-----------|----------|-----------------------------------------|
| <b>in</b> | <b>s</b> | Reference to used TimeStepping instance |
|-----------|----------|-----------------------------------------|

**void build ( EigenProblemSolver & e )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|           |          |                                               |
|-----------|----------|-----------------------------------------------|
| <b>in</b> | <b>e</b> | Reference to used EigenProblemSolver instance |
|-----------|----------|-----------------------------------------------|

**int runTransient ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is to be used only if a *TRANSIENT* analysis is required.

Returns

Return error from the linear system solver

**int runOneTimeStep ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is identical to the function *runTransient*.

Returns

Return error from the linear system solver

**int run ( )** [inherited]

Run the equation.

If the analysis (see function `setAnalysis`) is `STEADY_STATE`, then the function solves the stationary equation.

If the analysis is `TRANSIENT`, then the function performs time stepping until the final time is reached.

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = `NODE_DOF`, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE_FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT_FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE_FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                          |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute ePrev. This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be*, int *dof* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer *\_theSide*

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array *\_x[0]*, *\_x[1]*, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real\\_t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

## Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | pc | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul> |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |   |                                                                                 |
|--------|---|---------------------------------------------------------------------------------|
| in     | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | b | Vector containing right-hand side                                               |
| in,out | x | Vector containing initial guess of solution on input, actual solution on output |

#### 7.10.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

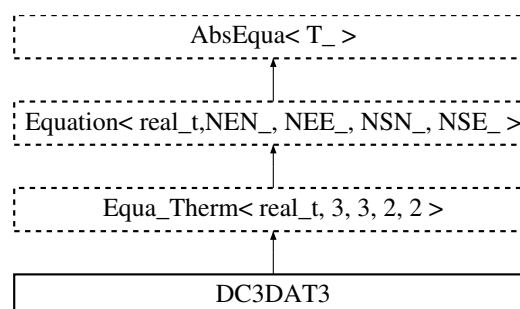
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.11 DC3DAT3 Class Reference

Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles.

Inheritance diagram for DC3DAT3:



#### Public Member Functions

- [DC3DAT3](#) ()  
*Default Constructor.*
- [DC3DAT3](#) (const [Element](#) \*el)  
*Constructor for an element.*

- **DC3DAT3** (const **Side** \*sd)  
*Constructor for a boundary side.*
- **DC3DAT3** (const **Element** \*el, const **Vect**< **real.t** > &u, **real.t** time=0.)  
*Constructor for an element (transient case).*
- **DC3DAT3** (const **Element** \*el, const **Vect**< **real.t** > &u, **real.t** time, **real.t** deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*
- **DC3DAT3** (const **Side** \*sd, const **Vect**< **real.t** > &u, **real.t** time=0.)  
*Constructor for a boundary side (transient case).*
- **DC3DAT3** (const **Side** \*sd, const **Vect**< **real.t** > &u, **real.t** time, **real.t** deltat, int scheme)  
*Constructor for a side (transient case) with specification of time integration scheme.*
- **~DC3DAT3** ()  
*Destructor.*
- void **LCapacityToLHS** (**real.t** coef=1)  
*Add lumped capacity matrix to left-hand side after multiplying it by coefficient coef.*
- void **LCapacityToRHS** (**real.t** coef=1)  
*Add lumped capacity contribution to right-hand side after multiplying it by coefficient coef.*
- void **LCapacity** (**real.t** coef=1)  
*Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient coef*
- void **CapacityToLHS** (**real.t** coef=1)  
*Add Consistent capacity matrix to left-hand side after multiplying it by coefficient coef*
- void **CapacityToRHS** (**real.t** coef=1)  
*Add Consistent capacity contribution to right-hand side after multiplying it by coefficient coef.*
- void **Capacity** (**real.t** coef=1)  
*Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient coef.*
- void **Diffusion** (**real.t** coef=1)  
*Add diffusion matrix to left-hand side after multiplying it by coefficient coef*
- void **Diffusion** (const **LocalMatrix**< **real.t**, 2, 2 > &diff, **real.t** coef=1)  
*Add diffusion matrix to left-hand side after multiplying it by coefficient coef*
- void **DiffusionToRHS** (**real.t** coef=1)  
*Add diffusion contribution to right-hand side after multiplying it by coefficient coef*
- void **BodyRHS** (**UserData**< **real.t** > &ud)  
*Add body right-hand side term to right-hand side after multiplying it by coefficient coef*
- void **BodyRHS** (const **Vect**< **real.t** > &b, int opt=GLOBAL\_ARRAY)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (**real.t** flux)  
*Add boundary right-hand side term to right hand side.*
- void **BoundaryRHS** (const **Vect**< **real.t** > &sf, int opt=GLOBAL\_ARRAY)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- **Point**< **real.t** > & **Grad** (const **Vect**< **real.t** > &u)  
*Return gradient of a vector in element.*
- void **build** ()  
*Build the linear system without solving.*
- virtual void **setStab** ()  
*Set stabilized formulation.*
- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*

- void `setCapacity` ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void `setDiffusion` ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- virtual void `Convection` (`real_t` coef=1.)  
*Add convection term to left-hand side.*
- virtual void `ConvectionToRHS` (`real_t` coef=1.)  
*Add convection term to right-hand side.*
- void `setConvection` ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void `build` (`TimeStepping` &s)  
*Build the linear system of equations.*
- void `build` (`EigenProblemSolver` &e)  
*Build the linear system for an eigenvalue problem.*
- int `runTransient` ()  
*Run one time step.*
- int `runOneTimeStep` ()  
*Run one time step.*
- int `run` ()  
*Run the equation.*
- void `setRhoCp` (const `real_t` &rhocp)  
*Set product of Density by Specific heat (constants)*
- void `setConductivity` (const `real_t` &diff)  
*Set (constant) thermal conductivity.*
- void `RhoCp` (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void `Conduc` (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void `updateBC` (const `Element` &el, const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `updateBC` (const `Vect`< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void `DiagBC` (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void `LocalNodeVector` (`Vect`< T\_ > &b)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be, int dof)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NEN\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< T\_ > &b, `LocalVect`< T\_, NSE\_ > &be)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize `Element` Vector.*

- void [SideVector](#) (const [Vect](#)< T\_ > &b)  
*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

- void **DGElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **AxbAssembly** (const **Element** &el, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void **AxbAssembly** (const **Side** &sd, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- void **setInitialSolution** (const **Vect**< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t **setMaterialProperty** (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void **setMesh** (**Mesh** &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- **Mesh** & **getMesh** () const  
*Return reference to **Mesh** instance.*
- **LinearSolver**< T\_ > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int **SolveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_ > **eMat**  
***LocalMatrix** instance containing local matrix associated to current element.*
- **LocalMatrix**< T\_, NSE\_ > **sMat**  
***LocalMatrix** instance containing local matrix associated to current side.*
- **LocalVect**< T\_, NEE\_ > **ePrev**  
***LocalVect** instance containing local vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRHS**  
***LocalVect** instance containing local right-hand side vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRes**  
***LocalVect** instance containing local residual vector associated to current element.*
- **LocalVect**< T\_, NSE\_ > **sRHS**  
***LocalVect** instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.11.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles.

Note that members calculating element arrays have as an argument a real `coef` that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.11.2 Constructor & Destructor Documentation

#### DC3DAT3 ( )

Default Constructor.

Constructs an empty equation.

#### DC3DAT3 ( const Element \* *el* )

Constructor for an element.

Parameters

|                 |                 |                     |
|-----------------|-----------------|---------------------|
| <code>in</code> | <code>el</code> | Pointer to element. |
|-----------------|-----------------|---------------------|

#### DC3DAT3 ( const Side \* *sd* )

Constructor for a boundary side.

Parameters

|                 |                 |                  |
|-----------------|-----------------|------------------|
| <code>in</code> | <code>sd</code> | Pointer to side. |
|-----------------|-----------------|------------------|

#### DC3DAT3 ( const Element \* *el*, const Vect< real\_t > & *u*, real\_t *time* = 0. )

Constructor for an element (transient case).

Parameters

|                 |                   |                                                                            |
|-----------------|-------------------|----------------------------------------------------------------------------|
| <code>in</code> | <code>el</code>   | Pointer to element                                                         |
| <code>in</code> | <code>u</code>    | <a href="#">Vect</a> instance that contains solution at previous time step |
| <code>in</code> | <code>time</code> | Current time value [Default: 0]                                            |

#### DC3DAT3 ( const Element \* *el*, const Vect< real\_t > & *u*, real\_t *time*, real\_t *deltat*, int *scheme* )

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|                 |                     |                                                                                                                                                                                                                              |
|-----------------|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>el</code>     | Pointer to element.                                                                                                                                                                                                          |
| <code>in</code> | <code>u</code>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                  |
| <code>in</code> | <code>time</code>   | Current time value.                                                                                                                                                                                                          |
| <code>in</code> | <code>deltat</code> | Value of time step                                                                                                                                                                                                           |
| <code>in</code> | <code>scheme</code> | Time Integration Scheme (): <ul style="list-style-type: none"> <li>• FORWARD_EULER for Forward Euler scheme, BACKWARD_EULER for Backward Euler scheme,</li> <li>• CRANK_NICOLSON for Crank-Nicolson Euler scheme.</li> </ul> |



**DC3DAT3 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time* = 0. )**

Constructor for a boundary side (transient case).

Parameters

|    |             |                                                                            |
|----|-------------|----------------------------------------------------------------------------|
| in | <i>sd</i>   | Pointer to side                                                            |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step |
| in | <i>time</i> | Current time value [Default: 0]                                            |

**DC3DAT3 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for a side (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                               |
|----|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i>     | Pointer to side                                                                                                                                                                                                                               |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                                   |
| in | <i>time</i>   | Current time value.                                                                                                                                                                                                                           |
| in | <i>deltat</i> | Value of time step                                                                                                                                                                                                                            |
| in | <i>scheme</i> | Time Integration Scheme (enumerated values) : <ul style="list-style-type: none"> <li>• FORWARD_EULER: Forward Euler scheme</li> <li>• BACKWARD_EULER: Backward Euler scheme</li> <li>• CRANK_NICOLSON: Crank-Nicolson Euler scheme</li> </ul> |

### 7.11.3 Member Function Documentation

**void LCapacityToLHS ( real.t *coef* = 1 ) [virtual]**

Add lumped capacity matrix to left-hand side after multiplying it by coefficient *coef*.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void LCapacityToRHS ( real.t *coef* = 1 ) [virtual]**

Add lumped capacity contribution to right-hand side after multiplying it by coefficient *coef*.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void LCapacity ( real.t *coef* = 1 )**

Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

**void CapacityToLHS ( *real.t coef* = 1 )** [virtual]

Add Consistent capacity matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void CapacityToRHS ( *real.t coef* = 1 )** [virtual]

Add Consistent capacity contribution to right-hand side after multiplying it by coefficient *coef*.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Capacity ( *real.t coef* = 1 )**

Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

**void Diffusion ( *real.t coef* = 1 )** [virtual]

Add diffusion matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void Diffusion ( *const LocalMatrix< real.t, 2, 2 > &diff*, *real.t coef* = 1 )**

Add diffusion matrix to left-hand side after multiplying it by coefficient *coef*

Case where the diffusivity matrix is given as an argument

Parameters

|           |             |                                                                         |
|-----------|-------------|-------------------------------------------------------------------------|
| <i>in</i> | <i>diff</i> | Instance of class <a href="#">DMatrix</a> containing diffusivity matrix |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]                      |

**void DiffusionToRHS ( *real.t coef* = 1 )** [virtual]

Add diffusion contribution to right-hand side after multiplying it by coefficient *coef*

To be used for explicit diffusion term

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void BodyRHS ( UserData< real.t > & ud )**

Add body right-hand side term to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |           |                                                                                                                      |
|-----------|-----------|----------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>ud</i> | Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source. |
|-----------|-----------|----------------------------------------------------------------------------------------------------------------------|

**void BodyRHS ( const Vect< real.t > & b, int opt = GLOBAL\_ARRAY )** [virtual]

Add body right-hand side term to right hand side.

Parameters

|           |            |                                                                                                                         |
|-----------|------------|-------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>b</i>   | Local vector (of size 3) containing source at element nodes.                                                            |
| <i>in</i> | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**void BoundaryRHS ( real.t flux )**

Add boundary right-hand side term to right hand side.

Parameters

|           |             |                                     |
|-----------|-------------|-------------------------------------|
| <i>in</i> | <i>flux</i> | Value of flux to impose on the side |
|-----------|-------------|-------------------------------------|

**void BoundaryRHS ( const Vect< real.t > & sf, int opt = GLOBAL\_ARRAY )** [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient *coef*

Parameters

|           |            |                                                                                                                         |
|-----------|------------|-------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>sf</i>  | Vector containing source at side nodes                                                                                  |
| <i>in</i> | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 2 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa.Therm< real.t, 3, 3, 2, 2 >](#).

**Point<real.t>& Grad ( const Vect< real.t > & u )**

Return gradient of a vector in element.

Parameters

|           |          |                                        |
|-----------|----------|----------------------------------------|
| <i>in</i> | <i>u</i> | Vector for which gradient is computed. |
|-----------|----------|----------------------------------------|

**virtual void setStab ( )** [virtual], [inherited]

Set stabilized formulation.

Stabilized variational formulations are to be used when the Peclet number is large.

By default, no stabilization is used.

**void build ( TimeStepping & s )** [inherited]

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

Parameters

|    |   |                                         |
|----|---|-----------------------------------------|
| in | s | Reference to used TimeStepping instance |
|----|---|-----------------------------------------|

**void build ( EigenProblemSolver & e )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |   |                                               |
|----|---|-----------------------------------------------|
| in | e | Reference to used EigenProblemSolver instance |
|----|---|-----------------------------------------------|

**int runTransient ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is to be used only if a *TRANSIENT* analysis is required.

Returns

Return error from the linear system solver

**int runOneTimeStep ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is identical to the function *runTransient*.

Returns

Return error from the linear system solver

**int run ( )** [inherited]

Run the equation.

If the analysis (see function *setAnalysis*) is *STEADY\_STATE*, then the function solves the stationary equation.

If the analysis is *TRANSIENT*, then the function performs time stepping until the final time is reached.

**void updateBC ( const Element & el, const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

## Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.



## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

## Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |        |                      |
|----|--------|----------------------|
| in | $exp$  | Algebraic expression |
| in | $prop$ | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

### 7.11.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

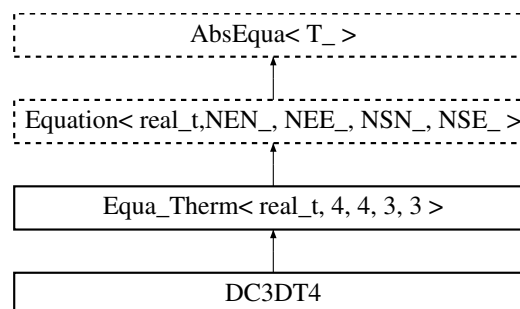
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.12 DC3DT4 Class Reference

Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra.

Inheritance diagram for DC3DT4:



### Public Member Functions

- [DC3DT4](#) ()  
*Default Constructor.*
- [DC3DT4](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [DC3DT4](#) (const [Side](#) \*sd)  
*Constructor for a boundary side.*
- [DC3DT4](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor for an element (transient case).*
- [DC3DT4](#) (const [Side](#) \*sd, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor for a boundary side (transient case).*
- [DC3DT4](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time, [real\\_t](#) deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*

- **DC3DT4** (const **Side** \*sd, const **Vect**< **real.t** > &u, **real.t** time, **real.t** deltat, int scheme)  
*Constructor for a side (transient case) with specification of time integration scheme.*
- **~DC3DT4** ()  
*Destructor.*
- void **build** ()  
*Build the linear system without solving.*
- void **LCapacity** (**real.t** coef=1.)  
*Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient coef.*
- void **LCapacityToLHS** (**real.t** coef=1)  
*Add lumped capacity matrix to left-hand side after multiplying it by coefficient coef*
- void **LCapacityToRHS** (**real.t** coef=1)  
*Add lumped capacity contribution to right-hand side after multiplying it by coefficient coef*
- void **Capacity** (**real.t** coef=1)  
*Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient coef.*
- void **CapacityToLHS** (**real.t** coef=1)  
*Add consistent capacity matrix to left-hand side after multiplying it by coefficient coef*
- void **CapacityToRHS** (**real.t** coef=1)  
*Add consistent capacity contribution to right-hand side after multiplying it by coefficient coef*
- void **Diffusion** (**real.t** coef=1)  
*Add diffusion matrix to left hand side after multiplying it by coefficient coef.*
- void **Diffusion** (const **DMatrix**< **real.t** > &diff, **real.t** coef=1)  
*Add diffusion matrix to left hand side after multiplying it by coefficient coef*
- void **DiffusionToRHS** (**real.t** coef=1)  
*Add diffusion contribution to right hand side after multiplying it by coefficient coef*
- void **Convection** (**real.t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **Convection** (const **Point**< **real.t** > &v, **real.t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **Convection** (const **Vect**< **Point**< **real.t** > > &v, **real.t** coef=1)  
*Add convection matrix to left-hand side after multiplying it by coefficient coef*
- void **RHS\_Convection** (const **Point**< **real.t** > &v, **real.t** coef=1.)  
*Add convection contribution to right-hand side after multiplying it by coefficient coef*
- void **BodyRHS** (**UserData**< **real.t** > &ud, **real.t** coef=1)  
*Add body right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BodyRHS** (const **Vect**< **real.t** > &b, int opt=GLOBAL\_ARRAY)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (**UserData**< **real.t** > &ud, **real.t** coef=1)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BoundaryRHS** (const **Vect**< **real.t** > &b, int opt=GLOBAL\_ARRAY)  
*Add boundary right-hand side term to right hand side after multiplying it by coefficient coef*
- void **BoundaryRHS** (**real.t** flux)  
*Add boundary right-hand side flux to right hand side.*
- **Point**< **real.t** > **Flux** () const  
*Return (constant) heat flux in element.*
- **Point**< **real.t** > **Grad** (const **Vect**< **real.t** > &u) const  
*Return gradient of vector u in element. u is a local vector.*

- void **Periodic** (real\_t coef=1.e20)  
*Add contribution of periodic boundary condition (by a penalty technique).*
- virtual void **setStab** ()  
*Set stabilized formulation.*
- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setCapacity** ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setDiffusion** ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- virtual void **ConvectionToRHS** (real\_t coef=1.)  
*Add convection term to right-hand side.*
- void **setConvection** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **build** (TimeStepping &s)  
*Build the linear system of equations.*
- void **build** (EigenProblemSolver &e)  
*Build the linear system for an eigenvalue problem.*
- int **runTransient** ()  
*Run one time step.*
- int **runOneTimeStep** ()  
*Run one time step.*
- int **run** ()  
*Run the equation.*
- void **setRhoCp** (const real\_t &rhocp)  
*Set product of Density by Specific heat (constants)*
- void **setConductivity** (const real\_t &diff)  
*Set (constant) thermal conductivity.*
- void **RhoCp** (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void **Conduc** (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void **updateBC** (const Element &el, const Vect< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const Vect< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (Vect< T\_ > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< T\_ > &b, LocalVect< T\_, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< T\_ > &b, LocalVect< T\_, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< T\_ > &b, LocalVect< T\_, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*



- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (**PETScVect**< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (**Matrix**< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**Vect**< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void **DGElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **DGElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_ > [eMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_ > [sMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > [ePrev](#)  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > [eRHS](#)  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > [eRes](#)  
*[LocalVect](#) instance containing local residual vector associated to current element.*
- [LocalVect](#)< T\_, NSE\_ > [sRHS](#)  
*[LocalVect](#) instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.12.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra.

Note that members calculating element arrays have as an argument a real coef that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.12.2 Constructor & Destructor Documentation

#### DC3DT4 ( )

Default Constructor.

Constructs an empty equation.

#### DC3DT4 ( const [Element](#) \* el )

Constructor for an element.

Parameters

|    |    |                     |
|----|----|---------------------|
| in | el | Pointer to element. |
|----|----|---------------------|

#### DC3DT4 ( const [Side](#) \* sd )

Constructor for a boundary side.

Parameters

|    |                       |
|----|-----------------------|
| sd | [in] Pointer to side. |
|----|-----------------------|

#### DC3DT4 ( const [Element](#) \* el, const [Vect](#)< [real\\_t](#) > & u, [real\\_t](#) time = 0. )

Constructor for an element (transient case).

Parameters

|    |      |                                                                             |
|----|------|-----------------------------------------------------------------------------|
| in | el   | Pointer to element.                                                         |
| in | u    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | time | Current time value [Default: 0].                                            |

#### DC3DT4 ( const [Side](#) \* sd, const [Vect](#)< [real\\_t](#) > & u, [real\\_t](#) time = 0. )

Constructor for a boundary side (transient case).

Parameters

|    |             |                                                                             |
|----|-------------|-----------------------------------------------------------------------------|
| in | <i>sd</i>   | Pointer to side.                                                            |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | <i>time</i> | Current time value [Default: 0].                                            |

**DC3DT4 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                          |
|----|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>     | Pointer to element.                                                                                                                                                                                                      |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                              |
| in | <i>time</i>   | Current time value.                                                                                                                                                                                                      |
| in | <i>deltat</i> | Value of time step                                                                                                                                                                                                       |
| in | <i>scheme</i> | Time Integration Scheme: <ul style="list-style-type: none"> <li>• FORWARD_EULER: Forward Euler scheme</li> <li>• BACKWARD_EULER: Backward Euler scheme</li> <li>• CRANK_NICOLSON: Crank-Nicolson Euler scheme</li> </ul> |

**DC3DT4 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for a side (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                         |
|----|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i>     | Pointer to side.                                                                                                                                                                                                                        |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                             |
| in | <i>time</i>   | Current time value.                                                                                                                                                                                                                     |
| in | <i>deltat</i> | Value of time step                                                                                                                                                                                                                      |
| in | <i>scheme</i> | Time Integration Scheme (): <ul style="list-style-type: none"> <li>• FORWARD_EULER: for Forward Euler scheme</li> <li>• BACKWARD_EULER: for Backward Euler scheme</li> <li>• CRANK_NICOLSON: for Crank-Nicolson Euler scheme</li> </ul> |

### 7.12.3 Member Function Documentation

**void LCapacity ( real.t *coef* = 1. )**

Add lumped capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|----|-------------|-----------------------------------------------------|

**void LCapacityToLHS ( real.t *coef* = 1 ) [virtual]**

Add lumped capacity matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void LCapacityToRHS ( real\_t coef = 1 )** [virtual]

Add lumped capacity contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void Capacity ( real\_t coef = 1 )**

Add Consistent capacity contribution to left and right-hand sides after multiplying it by coefficient *coef*.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

**void CapacityToLHS ( real\_t coef = 1 )** [virtual]

Add consistent capacity matrix to left-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void CapacityToRHS ( real\_t coef = 1 )** [virtual]

Add consistent capacity contribution to right-hand side after multiplying it by coefficient *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void Diffusion ( real\_t coef = 1 )** [virtual]

Add diffusion matrix to left hand side after multiplying it by coefficient *coef*.

Parameters

|           |             |                                                            |
|-----------|-------------|------------------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term (default value = 1). |
|-----------|-------------|------------------------------------------------------------|

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void Diffusion ( const DMatrix< real\_t > & diff, real\_t coef = 1 )**

Add diffusion matrix to left hand side after multiplying it by coefficient *coef*

Case where the diffusivity matrix is given as an argument.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>diff</i> | Diffusion matrix (class <a href="#">DMatrix</a> ).  |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void DiffusionToRHS ( *real.t coef* = 1 )** [virtual]

Add diffusion contribution to right hand side after multiplying it by coefficient *coef*  
To be used for explicit diffusion term

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 4, 4, 3, 3 >](#).

**void Convection ( *real.t coef* = 1 )** [virtual]

Add convection matrix to left-hand side after multiplying it by coefficient *coef*  
Case where velocity field has been previously defined

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Therm< real.t, 4, 4, 3, 3 >](#).

**void Convection ( const Point< *real.t* > & *v*, *real.t coef* = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*  
Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>v</i>    | Constant velocity vector                            |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void Convection ( const Vect< Point< *real.t* > > & *v*, *real.t coef* = 1 )**

Add convection matrix to left-hand side after multiplying it by coefficient *coef*  
Case where velocity field is given by a vector *v*.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>v</i>    | Velocity vector.                                    |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void RHS.Convection ( const Point< *real.t* > & *v*, *real.t coef* = 1. )**

Add convection contribution to right-hand side after multiplying it by coefficient *coef*  
To be used for explicit convection term.

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <i>in</i> | <i>v</i>    | Velocity vector.                                    |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |

**void BodyRHS ( UserData< *real.t* > & *ud*, *real.t coef* = 1 )**

Add body right-hand side term to right hand side after multiplying it by coefficient *coef*  
Parameters

|           |             |                                                                                                                      |
|-----------|-------------|----------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>ud</i>   | Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source. |
| <i>in</i> | <i>coef</i> | Coefficient to multiply by added term [Default: 1].                                                                  |

**void BodyRHS ( const Vect< real\_t > & *b*, int *opt* = GLOBAL\_ARRAY )** [virtual]

Add body right-hand side term to right hand side.

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Local vector containing source at element nodes.                                                                        |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 4 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void BoundaryRHS ( UserData< real\_t > &ud, real\_t coef = 1 )**

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Parameters

|    |             |                                                                                                                      |
|----|-------------|----------------------------------------------------------------------------------------------------------------------|
| in | <i>ud</i>   | Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source. |
| in | <i>coef</i> | Value by which the added term is multiplied [Default: 1].                                                            |

**void BoundaryRHS ( const Vect< real\_t > &b, int opt = GLOBAL\_ARRAY ) [virtual]**

Add boundary right-hand side term to right hand side after multiplying it by coefficient coef

Case where body source is given by a vector

Parameters

|    |            |                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>   | Vector containing source at side nodes.                                                                                 |
| in | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented from [Equa\\_Therm< real\\_t, 4, 4, 3, 3 >](#).

**void BoundaryRHS ( real\_t flux )**

Add boundary right-hand side flux to right hand side.

Parameters

|    |             |                                         |
|----|-------------|-----------------------------------------|
| in | <i>flux</i> | Vector containing source at side nodes. |
|----|-------------|-----------------------------------------|

**void Periodic ( real\_t coef = 1.e20 )**

Add contribution of periodic boundary condition (by a penalty technique).

Boundary nodes where periodic boundary conditions are to be imposed must have codes equal to PERIODIC.A on one side and PERIODIC.B on the opposite side.

Parameters

|    |             |                                              |
|----|-------------|----------------------------------------------|
| in | <i>coef</i> | Value of penalty parameter [Default: 1.e20]. |
|----|-------------|----------------------------------------------|

**virtual void setStab ( ) [virtual], [inherited]**

Set stabilized formulation.

Stabilized variational formulations are to be used when the Pclet number is large.

By default, no stabilization is used.

**void build ( TimeStepping &s ) [inherited]**

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:



- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

Parameters

|           |          |                                         |
|-----------|----------|-----------------------------------------|
| <b>in</b> | <i>s</i> | Reference to used TimeStepping instance |
|-----------|----------|-----------------------------------------|

**void build ( EigenProblemSolver & *e* )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|           |          |                                               |
|-----------|----------|-----------------------------------------------|
| <b>in</b> | <i>e</i> | Reference to used EigenProblemSolver instance |
|-----------|----------|-----------------------------------------------|

**int runTransient ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is to be used only if a *TRANSIENT* analysis is required.

Returns

Return error from the linear system solver

**int runOneTimeStep ( )** [inherited]

Run one time step.

This function performs one time step in equation solving. It is identical to the function *runTransient*.

Returns

Return error from the linear system solver

**int run ( )** [inherited]

Run the equation.

If the analysis (see function *setAnalysis*) is *STEADY\_STATE*, then the function solves the stationary equation.

If the analysis is *TRANSIENT*, then the function performs time stepping until the final time is reached.

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

## Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|         |   |                                                                                 |
|---------|---|---------------------------------------------------------------------------------|
| in      | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in      | b | Vector containing right-hand side                                               |
| in, out | x | Vector containing initial guess of solution on input, actual solution on output |

### 7.12.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

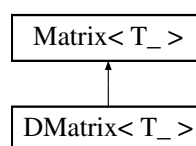
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.13 DMatrix< T\_ > Class Template Reference

To handle dense matrices.

Inheritance diagram for DMatrix< T\_ >:



### Public Member Functions

- [DMatrix](#) ()  
*Default constructor.*
- [DMatrix](#) (size\_t nr)  
*Constructor for a matrix with **nr** rows and **nr** columns.*
- [DMatrix](#) (size\_t nr, size\_t nc)  
*Constructor for a matrix with **nr** rows and **nc** columns.*
- [DMatrix](#) (Vect< T\_ > &v)  
*Constructor that uses a [Vect](#) instance. The class uses the memory space occupied by this vector.*
- [DMatrix](#) (const [DMatrix](#)< T\_ > &m)  
*Copy Constructor.*
- [~DMatrix](#) ()  
*Destructor.*
- void [setDiag](#) ()  
*Store diagonal entries in a separate internal vector.*
- void [setDiag](#) (const T\_ &a)  
*Set matrix as diagonal and assign its diagonal entries as a constant.*
- void [setDiag](#) (const vector< T\_ > &d)

- Set matrix as diagonal and assign its diagonal entries.*
- void **setSize** (size\_t **size**)  
*Set size (number of rows) of matrix.*
- void **setSize** (size\_t **nr**, size\_t **nc**)  
*Set size (number of rows and columns) of matrix.*
- void **getColumn** (size\_t **j**, Vect< T\_ > &**v**) const  
*Get j-th column vector.*
- Vect< T\_ > **getColumn** (size\_t **j**) const  
*Get j-th column vector.*
- void **getRow** (size\_t **i**, Vect< T\_ > &**v**) const  
*Get i-th row vector.*
- Vect< T\_ > **getRow** (size\_t **i**) const  
*Get i-th row vector.*
- void **set** (size\_t **i**, size\_t **j**, const T\_ &**val**)  
*Assign a constant value to an entry of the matrix.*
- void **setRow** (size\_t **i**, const Vect< T\_ > &**v**)  
*Copy a given vector to a prescribed row in the matrix.*
- void **setColumn** (size\_t **i**, const Vect< T\_ > &**v**)  
*Copy a given vector to a prescribed column in the matrix.*
- void **MultAdd** (T\_ **a**, const Vect< T\_ > &**x**, Vect< T\_ > &**y**) const  
*Multiply matrix by vector  $a \cdot x$  and add result to  $y$ .*
- void **MultAdd** (const Vect< T\_ > &**x**, Vect< T\_ > &**y**) const  
*Multiply matrix by vector  $x$  and add result to  $y$ .*
- void **Mult** (const Vect< T\_ > &**x**, Vect< T\_ > &**y**) const  
*Multiply matrix by vector  $x$  and save result in  $y$ .*
- void **TMult** (const Vect< T\_ > &**x**, Vect< T\_ > &**y**) const  
*Multiply transpose of matrix by vector  $x$  and add result in  $y$ .*
- void **add** (size\_t **i**, size\_t **j**, const T\_ &**val**)  
*Add constant  $val$  to entry  $(i, j)$  of the matrix.*
- void **Axpy** (T\_ **a**, const DMatrix< T\_ > &**m**)  
*Add to matrix the product of a matrix by a scalar.*
- void **Axpy** (T\_ **a**, const Matrix< T\_ > \***m**)  
*Add to matrix the product of a matrix by a scalar.*
- int **setQR** ()  
*Construct a QR factorization of the matrix.*
- int **setTransQR** ()  
*Construct a QR factorization of the transpose of the matrix.*
- int **solveQR** (const Vect< T\_ > &**b**, Vect< T\_ > &**x**)  
*Solve a linear system by QR decomposition.*
- int **solveTransQR** (const Vect< T\_ > &**b**, Vect< T\_ > &**x**)  
*Solve a transpose linear system by QR decomposition.*
- T\_ **operator()** (size\_t **i**, size\_t **j**) const  
*Operator () (Constant version). Return  $a(i, j)$*
- T\_ & **operator()** (size\_t **i**, size\_t **j**)  
*Operator () (Non constant version). Return  $a(i, j)$*
- int **setLU** ()

- Factorize the matrix (LU factorization)*

  - int `setTransLU` ()
- Factorize the transpose of the matrix (LU factorization)*

  - int `solve` (`Vect`< T\_ > &`b`)
- Solve linear system.*

  - int `solveTrans` (`Vect`< T\_ > &`b`)
- Solve the transpose linear system.*

  - int `solve` (const `Vect`< T\_ > &`b`, `Vect`< T\_ > &`x`)
- Solve linear system.*

  - int `solveTrans` (const `Vect`< T\_ > &`b`, `Vect`< T\_ > &`x`)
- Solve the transpose linear system.*

  - `DMatrix` & `operator=` (`DMatrix`< T\_ > &`m`)
- Operator =*

  - `DMatrix` & `operator+=` (const `DMatrix`< T\_ > &`m`)
- Operator +=.*

  - `DMatrix` & `operator-=` (const `DMatrix`< T\_ > &`m`)
- Operator -=.*

  - `DMatrix` & `operator=` (const T\_ &`x`)
- Operator =*

  - `DMatrix` & `operator*=` (const T\_ &`x`)
- Operator \*=*

  - `DMatrix` & `operator+=` (const T\_ &`x`)
- Operator +=*

  - `DMatrix` & `operator-=` (const T\_ &`x`)
- Operator -=*

  - T\_ \* `getArray` () const
- Return matrix as C-Array.*

  - T\_ `get` (size\_t `i`, size\_t `j`) const
- Return entry (i, j) of matrix.*

  - size\_t `getNbRows` () const
- Return number of rows.*

  - size\_t `getNbColumns` () const
- Return number of columns.*

  - void `setPenal` (real\_t `p`)
- Set Penalty Parameter (For boundary condition prescription).*

  - void `setDiagonal` ()
- Set the matrix as diagonal.*

  - void `setDiagonal` (`Mesh` &`mesh`)
- Initialize matrix storage in the case where only diagonal terms are stored.*

  - T\_ `getDiag` (size\_t `k`) const
- Return k-th diagonal entry of matrix.*

  - size\_t `size` () const
- Return matrix dimension (Number of rows and columns).*

  - void `Assembly` (const `Element` &`el`, T\_ \*`a`)
- Assembly of element matrix into global matrix.*

  - void `Assembly` (const `Element` &`el`, const `DMatrix`< T\_ > &`a`)

- Assembly of element matrix into global matrix.*
- void [Assembly](#) (const [Side](#) &sd, T\_ \*a)
- Assembly of side matrix into global matrix.*
- void [Assembly](#) (const [Side](#) &sd, const [DMatrix](#)< T\_ > &a)
- Assembly of side matrix into global matrix.*
- void [Prescribe](#) ([Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)
- Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.*
- void [Prescribe](#) (int dof, int code, [Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)
- Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- void [Prescribe](#) ([Vect](#)< T\_ > &b, int flag=0)
- Impose by a penalty method a homogeneous (=0) essential boundary condition.*
- void [Prescribe](#) (size\_t dof, [Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)
- Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- void [PrescribeSide](#) ()
- Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- virtual int [Factor](#) ()=0
- Factorize matrix. Available only if the storage class enables it.*
- int [FactorAndSolve](#) ([Vect](#)< T\_ > &b)
- Factorize matrix and solve the linear system.*
- int [FactorAndSolve](#) (const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Factorize matrix and solve the linear system.*
- size\_t [getLength](#) () const
- Return number of stored terms in matrix.*
- int [isDiagonal](#) () const
- Say if matrix is diagonal or not.*
- int [isFactorized](#) () const
- Say if matrix is factorized or not.*
- virtual size\_t [getColInd](#) (size\_t i) const
- Return Column index for column i (See the description for class [SpMatrix](#)).*
- virtual size\_t [getRowPtr](#) (size\_t i) const
- Return Row pointer for row i (See the description for class [SpMatrix](#)).*
- T\_ [operator](#)() (size\_t i) const
- Operator () with one argument (Constant version).*
- T\_ & [operator](#)() (size\_t i)
- Operator () with one argument (Non Constant version).*
- T\_ & [operator](#)[] (size\_t k)
- Operator [] (Non constant version).*
- T\_ [operator](#)[] (size\_t k) const
- Operator [] (Constant version).*
- [Matrix](#) & [operator](#)+= (const [Matrix](#)< T\_ > &m)
- Operator +=.*
- [Matrix](#) & [operator](#)-= (const [Matrix](#)< T\_ > &m)
- Operator -=.*

### 7.13.1 Detailed Description

**template<class T\_>class OFELI::DMatrix< T\_ >**

To handle dense matrices.

This class enables storing and manipulating general dense matrices. Matrices can be square or rectangle ones.

Template Parameters

|           |                                                 |
|-----------|-------------------------------------------------|
| <i>T_</i> | Data type (double, float, complex<double>, ...) |
|-----------|-------------------------------------------------|

### 7.13.2 Constructor & Destructor Documentation

#### **DMatrix ( )**

Default constructor.

Initializes a zero-dimension matrix.

#### **DMatrix ( size\_t *nr* )**

Constructor for a matrix with *nr* rows and *nr* columns.

Matrix entries are set to 0.

#### **DMatrix ( size\_t *nr*, size\_t *nc* )**

Constructor for a matrix with *nr* rows and *nc* columns.

[Matrix](#) entries are set to 0.

#### **DMatrix ( Vect< T\_ > & *v* )**

Constructor that uses a [Vect](#) instance. The class uses the memory space occupied by this vector.

Parameters

|           |          |                |
|-----------|----------|----------------|
| <i>in</i> | <i>v</i> | Vector to copy |
|-----------|----------|----------------|

#### **DMatrix ( const DMatrix< T\_ > & *m* )**

Copy Constructor.

Parameters

|           |          |                |
|-----------|----------|----------------|
| <i>in</i> | <i>m</i> | Matrix to copy |
|-----------|----------|----------------|

### 7.13.3 Member Function Documentation

#### **void setDiag ( const T\_ & *a* )**

Set matrix as diagonal and assign its diagonal entries as a constant.

Parameters

|           |          |                                         |
|-----------|----------|-----------------------------------------|
| <i>in</i> | <i>a</i> | Value to assign to all diagonal entries |
|-----------|----------|-----------------------------------------|

#### **void setDiag ( const vector< T\_ > & *d* )**

Set matrix as diagonal and assign its diagonal entries.

Parameters

|           |          |                                                     |
|-----------|----------|-----------------------------------------------------|
| <i>in</i> | <i>d</i> | Vector entries to assign to matrix diagonal entries |
|-----------|----------|-----------------------------------------------------|

#### **void setSize ( size\_t *size* )**

Set size (number of rows) of matrix.



Parameters

|           |             |                             |
|-----------|-------------|-----------------------------|
| <b>in</b> | <i>size</i> | Number of rows and columns. |
|-----------|-------------|-----------------------------|

**void setSize ( size\_t *nr*, size\_t *nc* )**

Set size (number of rows and columns) of matrix.

Parameters

|           |           |                    |
|-----------|-----------|--------------------|
| <b>in</b> | <i>nr</i> | Number of rows.    |
| <b>in</b> | <i>nc</i> | Number of columns. |

**void getColumn ( size\_t *j*, Vect< T\_ > & *v* ) const**

Get *j*-th column vector.

Parameters

|            |          |                                                                       |
|------------|----------|-----------------------------------------------------------------------|
| <b>in</b>  | <i>j</i> | Index of column to extract                                            |
| <b>out</b> | <i>v</i> | Reference to <a href="#">Vect</a> instance where the column is stored |

Remarks

Vector *v* does not need to be sized before. It is resized in the function

**Vect<T\_> getColumn ( size\_t *j* ) const**

Get *j*-th column vector.

Parameters

|           |          |                            |
|-----------|----------|----------------------------|
| <b>in</b> | <i>j</i> | Index of column to extract |
|-----------|----------|----------------------------|

Returns

[Vect](#) instance where the column is stored

Remarks

Vector *v* does not need to be sized before. It is resized in the function

**void getRow ( size\_t *i*, Vect< T\_ > & *v* ) const**

Get *i*-th row vector.

Parameters

|            |          |                                                                    |
|------------|----------|--------------------------------------------------------------------|
| <b>in</b>  | <i>i</i> | Index of row to extract                                            |
| <b>out</b> | <i>v</i> | Reference to <a href="#">Vect</a> instance where the row is stored |

Remarks

Vector *v* does not need to be sized before. It is resized in the function

**Vect<T\_> getRow ( size\_t *i* ) const**

Get *i*-th row vector.

Parameters

|    |          |                         |
|----|----------|-------------------------|
| in | <i>i</i> | Index of row to extract |
|----|----------|-------------------------|

Returns

[Vect](#) instance where the row is stored

Remarks

Vector *v* does not need to be sized before. It is resized in the function

**void set ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Assign a constant value to an entry of the matrix.

Parameters

|    |            |                                                      |
|----|------------|------------------------------------------------------|
| in | <i>i</i>   | row index of matrix                                  |
| in | <i>j</i>   | column index of matrix                               |
| in | <i>val</i> | Value to assign to <i>a</i> ( <i>i</i> , <i>j</i> ). |

Implements [Matrix< T\\_ >](#).

**void setRow ( size\_t *i*, const Vect< T\_ > & *v* )**

Copy a given vector to a prescribed row in the matrix.

Parameters

|    |          |                                       |
|----|----------|---------------------------------------|
| in | <i>i</i> | row index to be assigned              |
| in | <i>v</i> | <a href="#">Vect</a> instance to copy |

**void setColumn ( size\_t *i*, const Vect< T\_ > & *v* )**

Copy a given vector to a prescribed column in the matrix.

Parameters

|    |          |                                       |
|----|----------|---------------------------------------|
| in | <i>i</i> | column index to be assigned           |
| in | <i>v</i> | <a href="#">Vect</a> instance to copy |

**void MultAdd ( T\_ *a*, const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *a*\**x* and add result to *y*.

Parameters

|        |          |                                                |
|--------|----------|------------------------------------------------|
| in     | <i>a</i> | constant to multiply by                        |
| in     | <i>x</i> | Vector to multiply by <i>a</i>                 |
| in,out | <i>y</i> | on input, vector to add to. On output, result. |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *x* and add result to *y*.

Parameters

|        |     |                                                |
|--------|-----|------------------------------------------------|
| in     | $x$ | Vector to add to y                             |
| in,out | $y$ | on input, vector to add to. On output, result. |

Implements [Matrix< T\\_ >](#).**void Mult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply matrix by vector x and save result in y.

Parameters

|     |     |                    |
|-----|-----|--------------------|
| in  | $x$ | Vector to add to y |
| out | $y$ | Result.            |

Implements [Matrix< T\\_ >](#).**void TMult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply transpose of matrix by vector x and add result in y.

Parameters

|        |     |                                                |
|--------|-----|------------------------------------------------|
| in     | $x$ | Vector to add to y                             |
| in,out | $y$ | on input, vector to add to. On output, result. |

Implements [Matrix< T\\_ >](#).**void add ( size\_t i, size\_t j, const T\_ & val )** [virtual]

Add constant val to entry (i,j) of the matrix.

Parameters

|    |       |                 |
|----|-------|-----------------|
| in | $i$   | row index       |
| in | $j$   | column index    |
| in | $val$ | Constant to add |

Implements [Matrix< T\\_ >](#).**void Apxy ( T\_ a, const DMatrix< T\_ > & m )**

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                          |
|----|-----|--------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                    |
| in | $m$ | Matrix by which a is multiplied. The result is added to current instance |

**void Apxy ( T\_ a, const Matrix< T\_ > \* m )** [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                          |
|----|-----|--------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                    |
| in | $m$ | Matrix by which a is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**int setQR ( )**

Construct a QR factorization of the matrix.

This function constructs the QR decomposition using the Householder method. The upper triangular matrix R is returned in the upper triangle of the current matrix, except for the diagonal elements of R which are stored in an internal vector. The orthogonal matrix Q is represented as a product of n-1 Householder matrices  $Q_1 \dots Q_{n-1}$ , where  $Q_j = 1 - u_j u_j^T / c_j$ . The i-th component of  $u_j$  is zero for  $i = 1, \dots, j-1$  while the nonzero components are returned in  $a[i][j]$  for  $i = j, \dots, n$ .

Returns

0 if the decomposition was successful, k is the k-th row is singular

Remarks

The matrix can be square or rectangle

**int setTransQR ( )**

Construct a QR factorization of the transpose of the matrix.

This function constructs the QR decomposition using the Householder method. The upper triangular matrix R is returned in the upper triangle of the current matrix, except for the diagonal elements of R which are stored in an internal vector. The orthogonal matrix Q is represented as a product of n-1 Householder matrices  $Q_1 \dots Q_{n-1}$ , where  $Q_j = 1 - u_j u_j^T / c_j$ . The i-th component of  $u_j$  is zero for  $i = 1, \dots, j-1$  while the nonzero components are returned in  $a[i][j]$  for  $i = j, \dots, n$ .

Returns

0 if the decomposition was successful, k is the k-th row is singular

Remarks

The matrix can be square or rectangle

**int solveQR ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve a linear system by QR decomposition.

This function constructs the QR decomposition, if this was not already done by using the member function QR and solves the linear system

Parameters

|     |     |                                                                   |
|-----|-----|-------------------------------------------------------------------|
| in  | $b$ | Right-hand side vector                                            |
| out | $x$ | Solution vector. Must have been sized before using this function. |

Returns

The same value as returned by the function QR

**int solveTransQR ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve a transpose linear system by QR decomposition.

This function constructs the QR decomposition, if this was not already done by using the member function QR and solves the linear system

Parameters

|     |     |                                                                   |
|-----|-----|-------------------------------------------------------------------|
| in  | $b$ | Right-hand side vector                                            |
| out | $x$ | Solution vector. Must have been sized before using this function. |

Returns

The same value as returned by the function QR

**T\_ operator() ( size\_t i, size\_t j ) const** [virtual]

Operator () (Constant version). Return a(i,j)

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | row index    |
| in | $j$ | column index |

Implements [Matrix< T\\_ >](#).

**T\_& operator() ( size\_t i, size\_t j )** [virtual]

Operator () (Non constant version). Return a(i,j)

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | row index    |
| in | $j$ | column index |

Implements [Matrix< T\\_ >](#).

**int setLU ( )**

Factorize the matrix (LU factorization)

LU factorization of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- 0 if factorization was normally performed,
- n if the n-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

**int setTransLU ( )**

Factorize the transpose of the matrix (LU factorization)

LU factorization of the transpose of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- 0 if factorization was normally performed,
- n if the n-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

**int solve ( Vect< T\_ > & b )** [virtual]

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents is a factorization is performed. Naturally, if the the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

Implements [Matrix< T\\_ >](#).

**int solveTrans ( Vect< T\_ > & b )**

Solve the transpose linear system.

The linear system having the current instance as a transpose matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents is a factorization is performed. Naturally, if the the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents is a factorization is performed. Naturally, if the the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|     |     |                                                              |
|-----|-----|--------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side. |
| out | $x$ | <a href="#">Vect</a> instance that contains solution         |

Returns

- 0 if solution was normally performed,
- $n$  if the  $n$ -th pivot is null.

**int solveTrans ( const Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$  )**

Solve the transpose linear system.

The linear system having the current instance as a transpose matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|     |     |                                                              |
|-----|-----|--------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side. |
| out | $x$ | <a href="#">Vect</a> instance that contains solution         |

Returns

- 0 if solution was normally performed,
- $n$  if the  $n$ -th pivot is null.

**DMatrix& operator= ( DMatrix< T\_ > &  $m$  )**

Operator =

Copy matrix  $m$  to current matrix instance.

**DMatrix& operator+= ( const DMatrix< T\_ > &  $m$  )**

Operator +=.

Add matrix  $m$  to current matrix instance.

**DMatrix& operator-= ( const DMatrix< T\_ > &  $m$  )**

Operator -=.

Subtract matrix  $m$  from current matrix instance.

**DMatrix& operator= ( const T\_ &  $x$  )**

Operator =

Assign matrix to identity times  $x$

**DMatrix& operator\*= ( const T\_ &  $x$  )**

Operator \*=

Premultiply matrix entries by constant value  $x$ .

**DMatrix& operator+= ( const T\_ & x )**

Operator +=

Add constant value x to matrix entries

**DMatrix& operator-= ( const T\_ & x )**

Operator -=

Subtract constant value x from matrix entries.

**T\_\* getArray ( ) const**

Return matrix as C-Array.

Matrix is stored row by row.

**void setDiagonal ( Mesh & mesh )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t k ) const** [inherited]

Return k-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & el, T\_\* a )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & el, const DMatrix< T\_ > & a )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & sd, T\_\* a )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |



**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( int *dof*, int *code*, Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                           |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                        |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & *b*, int *flag* = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty

parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This function is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function setPenal.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                                 |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |          |                                                                                             |
|--------|----------|---------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|--------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- *n* if the *n*-th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator () with one argument (Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|           |          |             |
|-----------|----------|-------------|
| <i>in</i> | <i>i</i> | entry index |
|-----------|----------|-------------|

**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|           |          |             |
|-----------|----------|-------------|
| <i>in</i> | <i>i</i> | entry index |
|-----------|----------|-------------|

**T\_& operator[] ( size\_t k )** [inherited]

Operator [] (Non constant version).

Returns *k*-th stored element in matrix Index *k* starts at 0.

**T\_ operator[] ( size\_t k ) const** [inherited]

Operator [] (Constant version).

Returns *k*-th stored element in matrix Index *k* starts at 0.

**Matrix& operator+=( const Matrix< T\_ > & m )** [inherited]

Operator +=.

Add matrix *m* to current matrix instance.

**Matrix& operator-= ( const Matrix< T\_ > & m )** [inherited]

Operator -=.

Subtract matrix *m* from current matrix instance.

## 7.14 Domain Class Reference

To store and treat finite element geometric information.

## Public Member Functions

- [Domain](#) ()  
*Constructor of a null domain.*
- [Domain](#) (const string &file)  
*Constructor with an input file.*
- [~Domain](#) ()  
*Destructor.*
- void [setFile](#) (string file)  
*Set file containing [Domain](#) data.*
- void [setDim](#) (size\_t d)  
*Set space dimension.*
- size\_t [getDim](#) () const  
*Return space dimension.*
- void [setNbDOF](#) (size\_t n)  
*Set number of degrees of freedom.*
- size\_t [getNbDOF](#) () const  
*Return number of degrees of freedom.*
- size\_t [getNbVertices](#) () const  
*Return number of vertices.*
- size\_t [getNbLines](#) () const  
*Return number of lines.*
- size\_t [getNbContours](#) () const  
*Return number of contours.*
- size\_t [getNbHoles](#) () const  
*Return number of holes.*
- size\_t [getNbSubDomains](#) () const  
*Return number of sub-domains.*
- int [get](#) ()  
*Read domain data interactively.*
- void [get](#) (const string &file)  
*Read domain data from a data file.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to generated [Mesh](#) instance.*
- void [genGeo](#) (string file)  
*Generate geometry file.*
- void [genMesh](#) ()  
*Generate 2-D mesh.*
- void [genMesh](#) (const string &file)  
*Generate 2-D mesh and save in file ([OFELI](#) format)*
- void [genMesh](#) (string geo\_file, string bamg\_file, string mesh\_file)  
*Generate 2-D mesh and save geo, bamg and mesh file ([OFELI](#) format)*
- void [generateMesh](#) (const string &file)  
*Generate 2-D mesh using the BAMG mesh generator.*
- [Domain](#) & operator\*= (real\_t a)  
*Operator \*=*
- void [insertVertex](#) (real\_t x, real\_t y, real\_t h, int code)

*Insert a vertex.*

- void [insertLine](#) (size\_t n1, size\_t n2, int dc, int nc)

*Insert a straight line.*

- void [insertCircle](#) (size\_t n1, size\_t n2, size\_t n3, int dc, int nc)

*Insert a circular arc.*

- void [insertRequiredVertex](#) (size\_t v)

*Insert a required (imposed) vertex.*

- void [insertRequiredEdge](#) (size\_t e)

*Insert a required (imposed) edge (or line)*

- void [insertSubDomain](#) (size\_t n, int code)

*Insert subdomain.*

- void [insertSubDomain](#) (size\_t ln, int orient, int code)

*Insert subdomain.*

- [Point](#)< [real\\_t](#) > [getMinCoord](#) () const

*Return minimum coordinates of vertices.*

- [Point](#)< [real\\_t](#) > [getMaxCoord](#) () const

*Return maximum coordinates of vertices.*

- [real\\_t](#) [getMinh](#) () const

*Return minimal value of mesh size.*

### 7.14.1 Detailed Description

To store and treat finite element geometric information.

This class is essentially useful to construct data for mesh generators.

### 7.14.2 Constructor & Destructor Documentation

**Domain ( )**

Constructor of a null domain.

This constructor assigns maximal values of parameters.

**Domain ( const string & file )**

Constructor with an input file.

Parameters

|                    |                      |                                                  |
|--------------------|----------------------|--------------------------------------------------|
| <a href="#">in</a> | <a href="#">file</a> | Input file in the XML format defining the domain |
|--------------------|----------------------|--------------------------------------------------|

### 7.14.3 Member Function Documentation

**void get ( const string & file )**

Read domain data from a data file.

Parameters

|                    |                      |                                                 |
|--------------------|----------------------|-------------------------------------------------|
| <a href="#">in</a> | <a href="#">file</a> | Input file in <a href="#">Domain</a> XML format |
|--------------------|----------------------|-------------------------------------------------|

**void genMesh ( const string & file )**

Generate 2-D mesh and save in file ([OFELI](#) format)

Parameters

|           |             |                                        |
|-----------|-------------|----------------------------------------|
| <b>in</b> | <i>file</i> | File where the generated mesh is saved |
|-----------|-------------|----------------------------------------|

**void genMesh ( string *geo\_file*, string *bamg\_file*, string *mesh\_file* )**

Generate 2-D mesh and save geo, bamg and mesh file ([OFELI](#) format)

Parameters

|           |                  |                                        |
|-----------|------------------|----------------------------------------|
| <b>in</b> | <i>geo_file</i>  | Geo file                               |
| <b>in</b> | <i>bamg_file</i> | Bamg file                              |
| <b>in</b> | <i>mesh_file</i> | File where the generated mesh is saved |

**void generateMesh ( const string & *file* )**

Generate 2-D mesh using the BAMG mesh generator.

Parameters

|           |             |                                           |
|-----------|-------------|-------------------------------------------|
| <b>in</b> | <i>file</i> | that contains output mesh after execution |
|-----------|-------------|-------------------------------------------|

**Domain& operator\*= ( real\_t *a* )**

Operator \*=

Rescale domain coordinates by multiplying by a factor

Parameters

|           |          |                      |
|-----------|----------|----------------------|
| <b>in</b> | <i>a</i> | Value to multiply by |
|-----------|----------|----------------------|

**void insertVertex ( real\_t *x*, real\_t *y*, real\_t *h*, int *code* )**

Insert a vertex.

Parameters

|           |             |                         |
|-----------|-------------|-------------------------|
| <b>in</b> | <i>x</i>    | x-coordinate of vertex  |
| <b>in</b> | <i>y</i>    | y-coordinate of vertex  |
| <b>in</b> | <i>h</i>    | mesh size around vertex |
| <b>in</b> | <i>code</i> | code of coordinate      |

**void insertLine ( size\_t *n1*, size\_t *n2*, int *dc*, int *nc* )**

Insert a straight line.

Parameters

|           |           |                                                |
|-----------|-----------|------------------------------------------------|
| <b>in</b> | <i>n1</i> | Label of the first vertex of line              |
| <b>in</b> | <i>n2</i> | Label of the second vertex of line             |
| <b>in</b> | <i>dc</i> | Code to associate to created nodes (Dirichlet) |
| <b>in</b> | <i>nc</i> | Code to associate to line (Neumann)            |

**void insertCircle ( size\_t *n1*, size\_t *n2*, size\_t *n3*, int *dc*, int *nc* )**

Insert a circular arc.

Parameters

|           |           |                                                    |
|-----------|-----------|----------------------------------------------------|
| <b>in</b> | <i>n1</i> | Label of vertex defining the first end of the arc  |
| <b>in</b> | <i>n2</i> | Label of vertex defining the second end of the arc |
| <b>in</b> | <i>n3</i> | Label of vertex defining the center of the arc     |
| <b>in</b> | <i>dc</i> | Dirichlet code for nodes on the arc                |
| <b>in</b> | <i>nc</i> | Neumann code for sides on the arc                  |

**void insertRequiredVertex ( size\_t v )**

Insert a required (imposed) vertex.

Parameters

|           |          |                 |
|-----------|----------|-----------------|
| <b>in</b> | <i>v</i> | Label of vertex |
|-----------|----------|-----------------|

**void insertRequiredEdge ( size\_t e )**

Insert a required (imposed) edge (or line)

Parameters

|           |          |               |
|-----------|----------|---------------|
| <b>in</b> | <i>e</i> | Label of line |
|-----------|----------|---------------|

**void insertSubDomain ( size\_t n, int code )**

Insert subdomain.

Parameters

|           |             |  |
|-----------|-------------|--|
| <b>in</b> | <i>n</i>    |  |
| <b>in</b> | <i>code</i> |  |

**void insertSubDomain ( size\_t ln, int orient, int code )**

Insert subdomain.

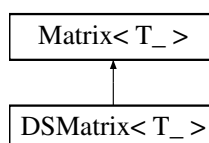
Parameters

|           |               |                             |
|-----------|---------------|-----------------------------|
| <b>in</b> | <i>ln</i>     | Line label                  |
| <b>in</b> | <i>orient</i> | Orientation (1 or -1)       |
| <b>in</b> | <i>code</i>   | Subdomain code or reference |

## 7.15 DSMatrix< T\_ > Class Template Reference

To handle symmetric dense matrices.

Inheritance diagram for DSMatrix< T\_ >:





## Public Member Functions

- `DSMatrix ()`  
*Default constructor.*
- `DSMatrix (size_t dim)`  
*Constructor that for a symmetric matrix with given number of rows.*
- `DSMatrix (const DSMatrix< T_ > &m)`  
*Copy Constructor.*
- `~DSMatrix ()`  
*Destructor.*
- `void setDiag ()`  
*Store diagonal entries in a separate internal vector.*
- `void setSize (size_t dim)`  
*Set size (number of rows) of matrix.*
- `void set (size_t i, size_t j, const T_ &val)`  
*Assign constant to entry  $(i, j)$  of the matrix.*
- `void setDiag (const T_ &a)`  
*Set matrix as diagonal and assign its diagonal entries as a constant.*
- `void setDiag (const vector< T_ > &d)`  
*Set matrix as diagonal and assign its diagonal entries.*
- `void add (size_t i, size_t j, const T_ &val)`  
*Add constant to an entry of the matrix.*
- `T_ operator() (size_t i, size_t j) const`  
*Operator  $()$  (Constant version).*
- `T_ & operator() (size_t i, size_t j)`  
*Operator  $()$  (Non constant version).*
- `DSMatrix< T_ > & operator= (const DSMatrix< T_ > &m)`  
*Operator = Copy matrix  $m$  to current matrix instance.*
- `DSMatrix< T_ > & operator= (const T_ &x)`  
*Operator = Assign matrix to identity times  $x$ .*
- `int setLDLt ()`  
*Factorize matrix  $(LDL^T)$*
- `void MultAdd (const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply matrix by vector  $a*x$  and add result to  $y$ .*
- `void MultAdd (T_ a, const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply matrix by vector  $a*x$  and add to  $y$ .*
- `void Mult (const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply matrix by vector  $x$  and save result in  $y$ .*
- `void TMult (const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply transpose of matrix by vector  $x$  and add result in  $y$ .*
- `void Axy (T_ a, const DSMatrix< T_ > &m)`  
*Add to matrix the product of a matrix by a scalar.*
- `void Axy (T_ a, const Matrix< T_ > *m)`  
*Add to matrix the product of a matrix by a scalar.*
- `int solve (Vect< T_ > &b)`  
*Solve linear system.*
- `int solve (const Vect< T_ > &b, Vect< T_ > &x)`

- Solve linear system.*
- `int setLDLt (const Vect< T_ > &b, Vect< T_ > &x)`  
*Solve a linear system using the LDLt (Crout) factorization.*
- `T_ * getArray () const`  
*Return matrix as C-Array. Matrix is stored row by row. Only lower triangle is stored.*
- `T_ get (size_t i, size_t j) const`  
*Return entry (i, j) of matrix.*
- `size_t getNbRows () const`  
*Return number of rows.*
- `size_t getNbColumns () const`  
*Return number of columns.*
- `void setPenal (real_t p)`  
*Set Penalty Parameter (For boundary condition prescription).*
- `void setDiagonal ()`  
*Set the matrix as diagonal.*
- `void setDiagonal (Mesh &mesh)`  
*Initialize matrix storage in the case where only diagonal terms are stored.*
- `T_ getDiag (size_t k) const`  
*Return k-th diagonal entry of matrix.*
- `size_t size () const`  
*Return matrix dimension (Number of rows and columns).*
- `void Assembly (const Element &el, T_ *a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Element &el, const DMatrix< T_ > &a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Side &sd, T_ *a)`  
*Assembly of side matrix into global matrix.*
- `void Assembly (const Side &sd, const DMatrix< T_ > &a)`  
*Assembly of side matrix into global matrix.*
- `void Prescribe (Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.*
- `void Prescribe (int dof, int code, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- `void Prescribe (Vect< T_ > &b, int flag=0)`  
*Impose by a penalty method a homegeneous (=0) essential boundary condition.*
- `void Prescribe (size_t dof, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- `void PrescribeSide ()`  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- `virtual int Factor ()=0`  
*Factorize matrix. Available only if the storage class enables it.*
- `int FactorAndSolve (Vect< T_ > &b)`  
*Factorize matrix and solve the linear system.*
- `int FactorAndSolve (const Vect< T_ > &b, Vect< T_ > &x)`  
*Factorize matrix and solve the linear system.*
- `size_t getLength () const`

- Return number of stored terms in matrix.
- `int isDiagonal () const`  
Say if matrix is diagonal or not.
- `int isFactorized () const`  
Say if matrix is factorized or not.
- `virtual size_t getColInd (size_t i) const`  
Return Column index for column *i* (See the description for class *SpMatrix*).
- `virtual size_t getRowPtr (size_t i) const`  
Return Row pointer for row *i* (See the description for class *SpMatrix*).
- `T_ operator() (size_t i) const`  
Operator () with one argument (Constant version).
- `T_ & operator() (size_t i)`  
Operator () with one argument (Non Constant version).
- `T_ & operator[] (size_t k)`  
Operator [] (Non constant version).
- `T_ operator[] (size_t k) const`  
Operator [] (Constant version).
- `Matrix & operator+= (const Matrix< T_ > &m)`  
Operator +=.
- `Matrix & operator+= (const T_ &x)`  
Operator +=.
- `Matrix & operator-= (const Matrix< T_ > &m)`  
Operator -=.
- `Matrix & operator-= (const T_ &x)`  
Operator -=.
- `Matrix & operator*= (const T_ &x)`  
Operator \*.=.

### 7.15.1 Detailed Description

`template<class T_>class OFELI::DSMatrix< T_ >`

To handle symmetric dense matrices.

This class enables storing and manipulating symmetric dense matrices.

Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.15.2 Constructor & Destructor Documentation

`DSMatrix ( size_t dim )`

Constructor that for a symmetric matrix with given number of rows.

Parameters

|                 |                  |                |
|-----------------|------------------|----------------|
| <code>in</code> | <code>dim</code> | Number of rows |
|-----------------|------------------|----------------|

`DSMatrix ( const DSMatrix< T_ > & m )`

Copy Constructor.

Parameters

|           |          |                                           |
|-----------|----------|-------------------------------------------|
| <b>in</b> | <i>m</i> | <a href="#">DSMatrix</a> instance to copy |
|-----------|----------|-------------------------------------------|

### 7.15.3 Member Function Documentation

**void setSize ( size\_t *dim* )**

Set size (number of rows) of matrix.

Parameters

|           |            |                             |
|-----------|------------|-----------------------------|
| <b>in</b> | <i>dim</i> | Number of rows and columns. |
|-----------|------------|-----------------------------|

**void set ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Assign constant to entry (*i*,*j*) of the matrix.

Parameters

|           |            |                                             |
|-----------|------------|---------------------------------------------|
| <b>in</b> | <i>i</i>   | row index                                   |
| <b>in</b> | <i>j</i>   | column index                                |
| <b>in</b> | <i>val</i> | value to assign to a( <i>i</i> , <i>j</i> ) |

Implements [Matrix< T\\_ >](#).

**void setDiag ( const T\_ & *a* )**

Set matrix as diagonal and assign its diagonal entries as a constant.

Parameters

|           |          |                                         |
|-----------|----------|-----------------------------------------|
| <b>in</b> | <i>a</i> | Value to assign to all diagonal entries |
|-----------|----------|-----------------------------------------|

**void setDiag ( const vector< T\_ > & *d* )**

Set matrix as diagonal and assign its diagonal entries.

Parameters

|           |          |                                                     |
|-----------|----------|-----------------------------------------------------|
| <b>in</b> | <i>d</i> | Vector entries to assign to matrix diagonal entries |
|-----------|----------|-----------------------------------------------------|

**void add ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Add constant to an entry of the matrix.

Parameters

|           |            |                                          |
|-----------|------------|------------------------------------------|
| <b>in</b> | <i>i</i>   | row index                                |
| <b>in</b> | <i>j</i>   | column index                             |
| <b>in</b> | <i>val</i> | value to add to a( <i>i</i> , <i>j</i> ) |

Implements [Matrix< T\\_ >](#).

**T\_ operator() ( size\_t *i*, size\_t *j* ) const** [virtual]

Operator () (Constant version).

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**T\_ & operator() ( size\_t  $i$ , size\_t  $j$  )** [virtual]

Operator () (Non constant version).

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**int setLDLt ( )**

Factorize matrix ( $LDL^T$  )

Returns

- 0, if factorization was normally performed,
- $n$ , if the  $n$ -th pivot is null.

**void MultAdd ( T\_  $a$ , const Vect< T\_ > &  $x$ , Vect< T\_ > &  $y$  ) const** [virtual]

Multiply matrix by vector  $a*x$  and add to  $y$ .

Parameters

|        |     |                                                                 |
|--------|-----|-----------------------------------------------------------------|
| in     | $a$ | Constant to multiply by matrix                                  |
| in     | $x$ | Vector to multiply by matrix                                    |
| in,out | $y$ | Vector to add to the result. $y$ contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void TMult ( const Vect< T\_ > &  $x$ , Vect< T\_ > &  $y$  ) const** [virtual]

Multiply transpose of matrix by vector  $x$  and add result in  $y$ .

Parameters

|        |     |                                                |
|--------|-----|------------------------------------------------|
| in     | $x$ | Vector to add to $y$                           |
| in,out | $y$ | on input, vector to add to. On output, result. |

Implements [Matrix< T\\_ >](#).

**void Axy ( T\_  $a$ , const DSMatrix< T\_ > &  $m$  )**

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                      |
| in | $m$ | Matrix by which $a$ is multiplied. The result is added to current instance |

**void Axy ( T\_  $a$ , const Matrix< T\_ > \*  $m$  )** [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                      |
| in | $m$ | Matrix by which $a$ is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**int solve ( Vect< T\_ > & b )** [virtual]

Solve linear system.

The matrix is factorized using the LDLt (Crout) decomposition. If this one is already factorized, no further factorization is performed. If the matrix has been modified the user has to refactorize it using the function setLDLt.

Parameters

|        |     |                                                                                              |
|--------|-----|----------------------------------------------------------------------------------------------|
| in,out | $b$ | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|-----|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- $n$  if the  $n$ -th pivot is null.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve linear system.

The matrix is factorized using the LDLt (Crout) decomposition. If this one is already factorized, no further factorization is performed. If the matrix has been modified the user has to refactorize it using the function setLDLt.

Parameters

|     |     |                                                              |
|-----|-----|--------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side. |
| out | $x$ | <a href="#">Vect</a> instance that contains solution         |

Returns

- 0 if solution was normally performed,
- $n$  if the  $n$ -th pivot is null.

**int setLDLt ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve a linear system using the LDLt (Crout) factorization.

This function solves a linear system. The LDLt factorization is performed if this was not already done using the function setLU.

Parameters

|     |     |                                                             |
|-----|-----|-------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side |
| out | $x$ | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- $n$  if the  $n$ -th pivot is null

**void setDiagonal ( Mesh & *mesh* )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t *k* ) const** [inherited]

Return *k*-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & *el*, T\_ \* *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_ \* *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty

parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.



Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( int dof, int code, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                              |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                           |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified<br>(dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & b, int flag = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|               |             |                                                                                                                                                                |
|---------------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i>     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                                                |
| <i>in,out</i> | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                                   |
| <i>in</i>     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed.                                                               |
| <i>in</i>     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|               |          |                                                                                             |
|---------------|----------|---------------------------------------------------------------------------------------------|
| <i>in,out</i> | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|---------------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|            |          |                                                             |
|------------|----------|-------------------------------------------------------------|
| <i>in</i>  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| <i>out</i> | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- n if the n-th pivot is null

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator ( ) with one argument (Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|           |          |             |
|-----------|----------|-------------|
| <i>in</i> | <i>i</i> | entry index |
|-----------|----------|-------------|

**T\_& operator() ( size\_t *i* )** [inherited]

Operator () with one argument (Non Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|           |          |             |
|-----------|----------|-------------|
| <i>in</i> | <i>i</i> | entry index |
|-----------|----------|-------------|

**T\_& operator[] ( size\_t *k* )** [inherited]

Operator [] (Non constant version).

Returns *k*-th stored element in matrix Index *k* starts at 0.

**T\_& operator[] ( size\_t *k* ) const** [inherited]

Operator [] (Constant version).

Returns *k*-th stored element in matrix Index *k* starts at 0.

**Matrix& operator+= ( const Matrix< T\_ > & *m* )** [inherited]

Operator +=.

Add matrix *m* to current matrix instance.

**Matrix& operator+= ( const T\_ & *x* )** [inherited]

Operator +=.

Add constant value *x* to all matrix entries.

**Matrix& operator-= ( const Matrix< T\_ > & *m* )** [inherited]

Operator -=.

Subtract matrix *m* from current matrix instance.

**Matrix& operator-= ( const T\_ & *x* )** [inherited]

Operator -=.

Subtract constant value *x* from all matrix entries.

**Matrix& operator\*= ( const T\_ & *x* )** [inherited]

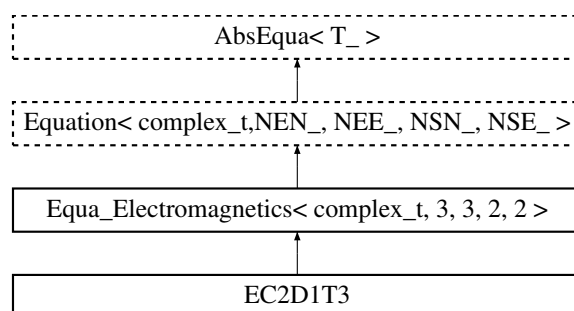
Operator \*.

Premultiply matrix entries by constant value *x*

## 7.16 EC2D1T3 Class Reference

Eddy current problems in 2-D domains using solenoidal approximation.

Inheritance diagram for EC2D1T3:



### Public Member Functions

- [EC2D1T3](#) ()  
*Default constructor.*
- [EC2D1T3](#) (const [Element](#) \*el)  
*Constructor using element data.*
- [EC2D1T3](#) (const [Side](#) \*side)  
*Constructor using side data.*
- [EC2D1T3](#) (const [Element](#) \*el, const [Vect](#)< [complex\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using element and previous time data.*
- [EC2D1T3](#) (const [Side](#) \*sd, const [Vect](#)< [complex\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using side and previous time data.*
- [~EC2D1T3](#) ()  
*Destructor.*
- void [Magnetic](#) ([real\\_t](#) omega, [real\\_t](#) coef=1.)  
*Add magnetic contribution to matrix.*
- void [Electric](#) ([real\\_t](#) coef=1.)  
*Add electric contribution to matrix.*
- [real\\_t](#) [Joule](#) ()  
*Compute Joule density in element.*
- [complex\\_t](#) [IntegMF](#) ()  
*Add element integral contribution.*
- [complex\\_t](#) [IntegND](#) (const [Vect](#)< [complex\\_t](#) > &h, int opt=[GLOBAL\\_ARRAY](#))  
*Compute integral of normal derivative on edge.*
- [real\\_t](#) [VacuumArea](#) ()  
*Add contribution to vacuum area calculation.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< [T\\_](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [T\\_](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [DiagBC](#) (int dof\_type=[NODE.DOF](#), int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*

- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (**PETScVect**< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (**Matrix**< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*

- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > eMat  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > sMat  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > ePrev  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*

- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRes](#)  
*LocalVect* instance containing local residual vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NSE<sub>-</sub> > [sRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void [MagneticPermeability](#) (const [real\\_t](#) &mu)  
*Set (constant) magnetic permeability.*
- void [MagneticPermeability](#) (const string &exp)  
*Set magnetic permeability given by an algebraic expression.*
- void [ElectricConductivity](#) (const [real\\_t](#) &sigma)  
*Set (constant) electric conductivity.*
- void [ElectricConductivity](#) (const string &exp)  
*set electric conductivity given by an algebraic expression*
- void [ElectricResistivity](#) (const [real\\_t](#) &rho)  
*Set (constant) electric resistivity.*
- void [ElectricResistivity](#) (const string &exp)  
*Set electric resistivity given by an algebraic expression.*
- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.16.1 Detailed Description

Eddy current problems in 2-D domains using solenoidal approximation.

Builds finite element arrays for time harmonic eddy current problems in 2-D domains with solenoidal configurations (Magnetic field has only one nonzero component). Magnetic field is constant in the vacuum, and then zero in the outer vacuum.

Uses 3-Node triangles.

The unknown is the time-harmonic magnetic induction (complex valued).

### 7.16.2 Constructor & Destructor Documentation

**EC2D1T3 ( const [Element](#) \* el )**

Constructor using element data.

Parameters

|                    |                    |                                             |
|--------------------|--------------------|---------------------------------------------|
| <a href="#">in</a> | <a href="#">el</a> | Pointer to <a href="#">Element</a> instance |
|--------------------|--------------------|---------------------------------------------|

**EC2D1T3 ( const [Side](#) \* side )**

Constructor using side data.

Parameters

|           |             |                                          |
|-----------|-------------|------------------------------------------|
| <b>in</b> | <i>side</i> | Pointer to <a href="#">Side</a> instance |
|-----------|-------------|------------------------------------------|

**EC2D1T3 ( const Element \* *el*, const Vect< complex.t > & *u*, const real.t & *time* = 0. )**

Constructor using element and previous time data.

Parameters

|           |             |                                             |
|-----------|-------------|---------------------------------------------|
| <b>in</b> | <i>el</i>   | Pointer to <a href="#">Element</a> instance |
| <b>in</b> | <i>u</i>    | Solution at previous iteration              |
| <b>in</b> | <i>time</i> | Time value [Default: 0]                     |

**EC2D1T3 ( const Side \* *sd*, const Vect< complex.t > & *u*, const real.t & *time* = 0. )**

Constructor using side and previous time data.

Parameters

|           |             |                                          |
|-----------|-------------|------------------------------------------|
| <b>in</b> | <i>sd</i>   | Pointer to <a href="#">Side</a> instance |
| <b>in</b> | <i>u</i>    | Solution at previous iteration           |
| <b>in</b> | <i>time</i> | Time value [Default: 0]                  |

### 7.16.3 Member Function Documentation

**void Magnetic ( real.t *omega*, real.t *coef* = 1. )**

Add magnetic contribution to matrix.

Parameters

|           |              |                                         |
|-----------|--------------|-----------------------------------------|
| <b>in</b> | <i>omega</i> | Angular frequency                       |
| <b>in</b> | <i>coef</i>  | Coefficient to multiply by [Default: 1] |

**void Electric ( real.t *coef* = 1. )**

Add electric contribution to matrix.

Parameters

|           |             |                                         |
|-----------|-------------|-----------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by [Default: 1] |
|-----------|-------------|-----------------------------------------|

**complex.t IntegND ( const Vect< complex.t > & *h*, int *opt* = GLOBAL\_ARRAY )**

Compute integral of normal derivative on edge.

Parameters

|           |            |                                                                                                                                  |
|-----------|------------|----------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>h</i>   | <a href="#">Vect</a> instance containing magnetic field at element nodes                                                         |
| <b>in</b> | <i>opt</i> | Vector <i>h</i> is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Note

This member function is to be called within each element, it detects boundary sides as the ones with nonzero code



**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

### 7.16.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.17 Edge Class Reference

To describe an edge.

### Public Member Functions

- [Edge](#) ()  
*Default Constructor.*
- [Edge](#) (size\_t label)  
*Constructor with label.*
- [Edge](#) (const [Edge](#) &ed)  
*Copy constructor.*
- [~Edge](#) ()  
*Destructor.*
- void [Add](#) ([Node](#) \*node)  
*Insert a node at end of list of nodes of edge.*
- void [setLabel](#) (size\_t i)  
*Assign label of edge.*
- void [setFirstDOF](#) (size\_t n)  
*Define First DOF.*
- void [setNbDOF](#) (size\_t nb\_dof)  
*Define number of DOF of edge.*
- void [DOF](#) (size\_t i, size\_t dof)  
*Define label of DOF.*
- void [setDOF](#) (size\_t &first\_dof, size\_t nb\_dof)  
*Define number of DOF.*
- void [setCode](#) (size\_t dof, int code)  
*Assign code code to DOF number dof.*
- void [AddNeighbor](#) ([Side](#) \*sd)  
*Add side pointed by sd to list of edge sides.*

- `size_t getLabel () const`  
*Return label of edge.*
- `size_t n () const`  
*Return label of edge.*
- `size_t getNbEq () const`  
*Return number of edge equations.*
- `size_t getNbDOF () const`  
*Return number of DOF.*
- `int getCode (size_t dof=1) const`  
*Return code for a given DOF of node.*
- `size_t getDOF (size_t i) const`  
*Return label of  $i$ -th DOF.*
- `size_t getFirstDOF () const`  
*Return number of first dof of node.*
- `Node * getPtrNode (size_t i) const`  
*List of element nodes.*
- `Node * operator() (size_t i) const`  
*Operator ().*
- `size_t getNodeLabel (size_t i) const`  
*Return node label.*
- `Side * getNeighborSide (size_t i) const`  
*Return pointer to neighbor  $i$ -th side.*
- `int isOnBoundary () const`  
*Say if current edge is a boundary edge or not.*
- `void setOnBoundary ()`  
*Say that the edge is on the boundary.*
- `Node * operator() (size_t i)`  
*Operator ().*

### 7.17.1 Detailed Description

To describe an edge.

Defines an edge of a 3-D finite element mesh. The edges are given in particular by a list of nodes. Each node can be accessed by the member function `getPtrNode`.

### 7.17.2 Constructor & Destructor Documentation

**Edge ( )**

Default Constructor.

Initializes data to zero

**Edge ( size\_t label )**

Constructor with label.

Define an edge by giving its `label`

### 7.17.3 Member Function Documentation

**void DOF ( size\_t i, size\_t dof )**

Define label of DOF.

Parameters

|           |            |           |
|-----------|------------|-----------|
| <b>in</b> | <i>i</i>   | DOF index |
| <b>in</b> | <i>dof</i> | Its label |

**void setDOF ( size\_t &first\_dof, size\_t nb\_dof )**

Define number of DOF.

Parameters

|               |                  |                                                    |
|---------------|------------------|----------------------------------------------------|
| <b>in,out</b> | <i>first_dof</i> | Label of the first DOF in input that is actualized |
| <b>in</b>     | <i>nb_dof</i>    | Number of DOF                                      |

**void setCode ( size\_t dof, int code )**

Assign code code to DOF number dof.

Parameters

|           |             |                              |
|-----------|-------------|------------------------------|
| <b>in</b> | <i>dof</i>  | index of dof for assignment. |
| <b>in</b> | <i>code</i> | Value of code to assign.     |

**int getCode ( size\_t dof = 1 ) const**

Return code for a given DOF of node.

Default value is 1

**Node\* operator() ( size\_t i ) const**

Operator ().

Return pointer to node of local label i.

**size\_t getNodeLabel ( size\_t i ) const**

Return node label.

Parameters

|           |          |                                                        |
|-----------|----------|--------------------------------------------------------|
| <b>in</b> | <i>i</i> | Local label of node for which global label is returned |
|-----------|----------|--------------------------------------------------------|

**int isOnBoundary ( ) const**

Say if current edge is a boundary edge or not.

Note this information is available only if boundary edges were determined. See class [Mesh](#)

**Node\* operator() ( size\_t i )**

Operator ().

Returns pointer to node of local label i

## 7.18 EdgeList Class Reference

Class to construct a list of edges having some common properties.

## Public Member Functions

- `EdgeList (Mesh &ms)`  
*Constructor using a `Mesh` instance.*
- `~EdgeList ()`  
*Destructor.*
- `void selectCode (int code, int dof=1)`  
*Select edges having a given code for a given degree of freedom.*
- `void unselectCode (int code, int dof=1)`  
*Unselect edges having a given code for a given degree of freedom.*
- `size_t getNbEdges () const`  
*Return number of selected edges.*
- `void top ()`  
*Reset list of edges at its top position (Non constant version)*
- `void top () const`  
*Reset list of edges at its top position (Constant version)*
- `Edge * get ()`  
*Return pointer to current edge and move to next one (Non constant version)*
- `Edge * get () const`  
*Return pointer to current edge and move to next one (Constant version)*

### 7.18.1 Detailed Description

Class to construct a list of edges having some common properties.

This class enables choosing multiple selection criteria by using function `select...`. However, the intersection of these properties must be empty.

### 7.18.2 Member Function Documentation

**`void selectCode ( int code, int dof = 1 )`**

Select edges having a given code for a given degree of freedom.

Parameters

|                 |                   |                                      |
|-----------------|-------------------|--------------------------------------|
| <code>in</code> | <code>code</code> | Code that edges share                |
| <code>in</code> | <code>dof</code>  | Degree of Freedom label [Default: 1] |

**`void unselectCode ( int code, int dof = 1 )`**

Unselect edges having a given code for a given degree of freedom.

Parameters

|                 |                   |                                      |
|-----------------|-------------------|--------------------------------------|
| <code>in</code> | <code>code</code> | Code of edges to exclude             |
| <code>in</code> | <code>dof</code>  | Degree of Freedom label [Default: 1] |

## 7.19 EigenProblemSolver Class Reference

Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, *i.e.* Find scalars  $\lambda$  and non-null vectors  $\mathbf{v}$  such that  $[\mathbf{K}]\{\mathbf{v}\} = \lambda[\mathbf{M}]\{\mathbf{v}\}$  where  $[\mathbf{K}]$  and  $[\mathbf{M}]$  are symmetric matrices. The eigenproblem can be originated from a PDE. For this, we will refer to the matrices  $\mathbf{K}$  and  $\mathbf{M}$  as *Stiffness* and *Mass* matrices respectively.

## Public Member Functions

- [EigenProblemSolver](#) ()  
*Default constructor.*
- [EigenProblemSolver](#) (DSMatrix< [real\\_t](#) > &K, int n=0)  
*Constructor for a dense symmetric matrix that computes the eigenvalues.*
- [EigenProblemSolver](#) (SkSMatrix< [real\\_t](#) > &K, SkSMatrix< [real\\_t](#) > &M, int n=0)  
*Constructor for Symmetric Skyline Matrices.*
- [EigenProblemSolver](#) (SkSMatrix< [real\\_t](#) > &K, Vect< [real\\_t](#) > &M, int n=0)  
*Constructor for Symmetric Skyline Matrices.*
- [EigenProblemSolver](#) (DSMatrix< [real\\_t](#) > &A, Vect< [real\\_t](#) > &ev, int n=0)  
*Constructor for a dense matrix that compute the eigenvalues.*
- [EigenProblemSolver](#) (AbsEqua< [real\\_t](#) > &eq, bool lumped=true)  
*Constuctor using partial differential equation.*
- [~EigenProblemSolver](#) ()  
*Destructor.*
- void [setMatrix](#) (SkSMatrix< [real\\_t](#) > &K, SkSMatrix< [real\\_t](#) > &M)  
*Set matrix instances (Symmetric matrices).*
- void [setMatrix](#) (SkSMatrix< [real\\_t](#) > &K, Vect< [real\\_t](#) > &M)  
*Set matrix instances (Symmetric matrices).*
- void [setMatrix](#) (DSMatrix< [real\\_t](#) > &K)  
*Set matrix instance (Symmetric matrix).*
- void [setPDE](#) (AbsEqua< [real\\_t](#) > &eq, bool lumped=true)  
*Define partial differential equation to solve.*
- int [run](#) (int nb=0)  
*Run the eigenproblem solver.*
- void [Assembly](#) (const [Element](#) &el, [real\\_t](#) \*eK, [real\\_t](#) \*eM)  
*Assemble element arrays into global matrices.*
- void [SAssembly](#) (const [Side](#) &sd, [real\\_t](#) \*sK)  
*Assemble side arrays into global matrix and right-hand side.*
- int [runSubSpace](#) (size\_t nb\_eigv, size\_t ss\_dim=0)  
*Run the subspace iteration solver.*
- void [setSubspaceDimension](#) (int dim)  
*Define the subspace dimension.*
- void [setMaxIter](#) (int max\_it)  
*set maximal number of iterations.*
- void [setTolerance](#) ([real\\_t](#) eps)  
*set tolerance value*
- int [checkSturm](#) (int &nb\_found, int &nb\_lost)  
*Check how many eigenvalues have been found using Sturm sequence method.*
- int [getNbIter](#) () const  
*Return actual number of performed iterations.*
- [real\\_t](#) [getEigenValue](#) (int n) const  
*Return the n-th eigenvalue.*
- void [getEigenVector](#) (int n, Vect< [real\\_t](#) > &v) const  
*Return the n-th eigenvector.*

### 7.19.1 Detailed Description

Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, *i.e.* Find scalars  $\lambda$  and non-null vectors  $v$  such that  $[K]\{v\} = \lambda[M]\{v\}$  where  $[K]$  and  $[M]$  are symmetric matrices. The eigenproblem can be originated from a PDE. For this, we will refer to the matrices  $K$  and  $M$  as *Stiffness* and *Mass* matrices respectively.

### 7.19.2 Constructor & Destructor Documentation

**EigenProblemSolver ( DSMatrix< real.t > & K, int n = 0 )**

Constructor for a dense symmetric matrix that computes the eigenvalues.

This constructor solves in place the eigenvalues problem and stores them in a vector (No need to use the function runSubSpace). The eigenvectors can be obtained by calling the member function getEigenvector.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $K$ | Matrix for which eigenmodes are sought.                                    |
| in | $n$ | Number of eigenvalues to extract. By default all eigenvalues are computed. |

**EigenProblemSolver ( SkSMatrix< real.t > & K, SkSMatrix< real.t > & M, int n = 0 )**

Constructor for Symmetric Skyline Matrices.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $K$ | "Stiffness" matrix                                                         |
| in | $M$ | Diagonal "Mass" matrix stored as a Vect instance                           |
| in | $n$ | Number of eigenvalues to extract. By default all eigenvalues are computed. |

Note

The generalized eigenvalue problem is defined by  $Kx = \lambda Mx$ , where  $K$  and  $M$  are referred to as stiffness and mass matrix.

**EigenProblemSolver ( SkSMatrix< real.t > & K, Vect< real.t > & M, int n = 0 )**

Constructor for Symmetric Skyline Matrices.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $K$ | "Stiffness" matrix                                                         |
| in | $M$ | Diagonal "Mass" matrix stored as a Vect instance                           |
| in | $n$ | Number of eigenvalues to extract. By default all eigenvalues are computed. |

Note

The generalized eigenvalue problem is defined by  $Kx = \lambda Mx$ , where  $K$  and  $M$  are referred to as stiffness and mass matrix.



**EigenProblemSolver ( DSMatrix< real\_t > & A, Vect< real\_t > & ev, int n = 0 )**

Constructor for a dense matrix that compute the eigenvalues.

This constructor solves in place the eigenvalues problem and stores them in a vector (No need to use the function runSubSpace). The eigenvectors can be obtained by calling the member function getEigenVector.

Parameters

|    |      |                                                                            |
|----|------|----------------------------------------------------------------------------|
| in | $A$  | <a href="#">Matrix</a> for which eigenmodes are sought.                    |
| in | $ev$ | Vector containing all computed eigenvalues sorted increasingly.            |
| in | $n$  | Number of eigenvalues to extract. By default all eigenvalues are computed. |

Remarks

The vector  $ev$  does not need to be sized before.

**EigenProblemSolver ( AbsEqua< real.t > &eq, bool lumped = true )**

Constructor using partial differential equation.

The used equation class must have been constructed using the [Mesh](#) instance

Parameters

|    |          |                                                                               |
|----|----------|-------------------------------------------------------------------------------|
| in | $eq$     | Reference to equation instance                                                |
| in | $lumped$ | Mass matrix is lumped ( <i>true</i> ) or not ( <i>false</i> ) [Default: true] |

### 7.19.3 Member Function Documentation

**void setMatrix ( SkSMatrix< real.t > &K, SkSMatrix< real.t > &M )**

Set matrix instances (Symmetric matrices).

This function is to be used when the default constructor is applied. Case where the mass matrix is consistent.

Parameters

|    |     |                           |
|----|-----|---------------------------|
| in | $K$ | Stiffness matrix instance |
| in | $M$ | Mass matrix instance      |

**void setMatrix ( SkSMatrix< real.t > &K, Vect< real.t > &M )**

Set matrix instances (Symmetric matrices).

This function is to be used when the default constructor is applied. Case where the mass matrix is (lumped) diagonal and stored in a vector.

Parameters

|    |     |                                                                   |
|----|-----|-------------------------------------------------------------------|
| in | $K$ | Stiffness matrix instance                                         |
| in | $M$ | Mass matrix instance where diagonal terms are stored as a vector. |

**void setMatrix ( DMatrix< real.t > &K )**

Set matrix instance (Symmetric matrix).

This function is to be used when the default constructor is applied. Case of a standard (not generalized) eigen problem is to be solved

Parameters

|    |     |                           |
|----|-----|---------------------------|
| in | $K$ | Stiffness matrix instance |
|----|-----|---------------------------|

**void setPDE ( AbsEqua< real\_t > & *eq*, bool *lumped* = *true* )**

Define partial differential equation to solve.

The used equation class must have been constructed using the [Mesh](#) instance

Parameters

|                 |                     |                                                                                             |
|-----------------|---------------------|---------------------------------------------------------------------------------------------|
| <code>in</code> | <code>eq</code>     | Reference to equation instance                                                              |
| <code>in</code> | <code>lumped</code> | Mass matrix is lumped ( <i>true</i> ) or not ( <i>false</i> ) [Default: <code>true</code> ] |

**int run ( int *nb* = 0 )**

Run the eigenproblem solver.

Parameters

|                 |                 |                                                                                 |
|-----------------|-----------------|---------------------------------------------------------------------------------|
| <code>in</code> | <code>nb</code> | Number of eigenvalues to be computed. By default, all eigenvalues are computed. |
|-----------------|-----------------|---------------------------------------------------------------------------------|

**void Assembly ( const Element & *el*, real\_t \* *eK*, real\_t \* *eM* )**

Assemble element arrays into global matrices.

This member function is to be called from finite element equation classes

Parameters

|                 |                 |                                                      |
|-----------------|-----------------|------------------------------------------------------|
| <code>in</code> | <code>el</code> | Reference to <a href="#">Element</a> class           |
| <code>in</code> | <code>eK</code> | Pointer to element stiffness (or assimilated) matrix |
| <code>in</code> | <code>eM</code> | Pointer to element mass (or assimilated) matrix      |

**void SAssembly ( const Side & *sd*, real\_t \* *sK* )**

Assemble side arrays into global matrix and right-hand side.

This member function is to be called from finite element equation classes

Parameters

|                 |                 |                                         |
|-----------------|-----------------|-----------------------------------------|
| <code>in</code> | <code>sd</code> | Reference to <a href="#">Side</a> class |
| <code>in</code> | <code>sK</code> | Pointer to side stiffness               |

**int runSubSpace ( size\_t *nb\_eigv*, size\_t *ss\_dim* = 0 )**

Run the subspace iteration solver.

This function runs the Bathe subspace iteration method.

Parameters

|                 |                      |                                                                                                                |
|-----------------|----------------------|----------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>nb_eigv</code> | Number of eigenvalues to be extracted                                                                          |
| <code>in</code> | <code>ss_dim</code>  | Subspace dimension. Must be at least equal to the number eigenvalues to seek. [Default: <code>nb_eigv</code> ] |

Returns

1: Normal execution. Convergence has been achieved. 2: Convergence for eigenvalues has not been attained.

**void setSubspaceDimension ( int *dim* )**

Define the subspace dimension.

Parameters

|    |            |                                                                                                                                                        |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dim</i> | Subspace dimension. Must be larger or equal to the number of wanted eigenvalues. By default this value will be set to the number of wanted eigenvalues |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|

**void setTolerance ( real.t *eps* )**

set tolerance value

Parameters

|    |            |                                                        |
|----|------------|--------------------------------------------------------|
| in | <i>eps</i> | Convergence tolerance for eigenvalues [Default: 1.e-8] |
|----|------------|--------------------------------------------------------|

**int checkSturm ( int & *nb\_found*, int & *nb\_lost* )**

Check how many eigenvalues have been found using Sturm sequence method.

Parameters

|     |                 |                                      |
|-----|-----------------|--------------------------------------|
| out | <i>nb_found</i> | number of eigenvalues actually found |
| out | <i>nb_lost</i>  | number of eigenvalues missing        |

Returns

- 0, Successful completion of subroutine.
- 1, No convergent eigenvalues found.

**void getEigenvector ( int *n*, Vect< real.t > & *v* ) const**

Return the n-th eigenvector.

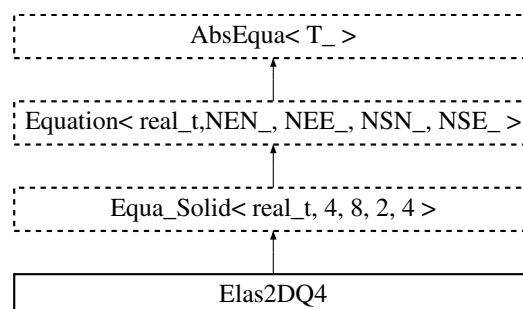
Parameters

|        |          |                                                                          |
|--------|----------|--------------------------------------------------------------------------|
| in     | <i>n</i> | Label of eigenvector (They are stored in ascending order of eigenvalues) |
| in,out | <i>v</i> | <a href="#">Vect</a> instance where the eigenvector is stored.           |

## 7.20 Elas2DQ4 Class Reference

To build element equations for 2-D linearized elasticity using 4-node quadrilaterals.

Inheritance diagram for Elas2DQ4:



## Public Member Functions

- **Elas2DQ4** ()  
*Default Constructor.*
- **Elas2DQ4** (const **Element** \*el)  
*Constructor using element data.*
- **Elas2DQ4** (const **Side** \*sd)  
*Constructor using side data.*
- **Elas2DQ4** (const **Element** \*element, const **Vect**< **real\_t** > &u, const **real\_t** &time=0.)  
*Constructor using element and previous time data.*
- **Elas2DQ4** (const **Side** \*side, const **Vect**< **real\_t** > &u, const **real\_t** &time=0.)  
*Constructor using side and previous time data.*
- **~Elas2DQ4** ()  
*Destructor.*
- void **PlaneStrain** ()  
*Set plane strain hypothesis.*
- void **PlaneStrain** (**real\_t** E, **real\_t** nu)  
*Set plane strain hypothesis by giving values of Young's modulus and Poisson ratio.*
- void **PlaneStress** ()  
*Set plane stress hypothesis.*
- void **PlaneStress** (**real\_t** E, **real\_t** nu)  
*Set plane stress hypothesis by giving values of Young's modulus and Poisson ratio.*
- void **LMassToLHS** (**real\_t** coef=1.)  
*Add element lumped mass contribution to matrix after multiplication by coef [Default: 1].*
- void **LMassToRHS** (**real\_t** coef=1.)  
*Add element lumped mass contribution to right-hand side after multiplication by coef [Default: 1].*
- void **LMass** (**real\_t** coef=1.)  
*Add element lumped mass contribution to matrix and right-hand side after multiplication by coef [Default: 1].*
- void **Mass** (**real\_t** coef=1.)  
*Add element consistent mass contribution to matrix and right-hand side after multiplication by coef [Default: 1].*
- void **Deviator** (**real\_t** coef=1.)  
*Add element deviatoric matrix to left-hand side after multiplication by coef [Default: 1].*
- void **DeviatorToRHS** (**real\_t** coef=1.)  
*Add element deviatoric contribution to right-hand side after multiplication by coef [Default: 1].*
- void **Dilatation** (**real\_t** coef=1.)  
*Add element dilatational contribution to left-hand side after multiplication by coef [Default: 1].*
- void **DilatationToRHS** (**real\_t** coef=1.)  
*Add element dilatational contribution to right hand side after multiplication by coef [Default: 1].*
- void **BodyRHS** (**UserData**< **real\_t** > &ud)  
*Add body right-hand side term to right hand side after multiplication by coef*
- void **BodyRHS** (const **Vect**< **real\_t** > &bf, int opt=GLOBAL\_ARRAY)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (**UserData**< **real\_t** > &ud)  
*Add boundary right-hand side term to right hand side after multiplication by coef*
- void **BoundaryRHS** (const **Vect**< **real\_t** > &sf)

- Add boundary right-hand side term to right hand side.*

  - `int SignoriniContact (UserData< real_t > &ud, real_t coef=1.e07)`

*Penalty Signorini contact side contribution to matrix and right-hand side.*
- `void Strain (LocalVect< real_t, 3 > &eps)`

*Calculate strains at element barycenter.*
- `void Stress (LocalVect< real_t, 3 > &s, real_t &vm)`

*Calculate principal stresses and Von-Mises stress at element barycenter.*
- `void Stress (LocalVect< real_t, 3 > &sigma, LocalVect< real_t, 3 > &s, real_t &vm)`

*Calculate principal stresses and Von-Mises stress at element barycenter.*
- `virtual void MassToLHS (real_t coef=1)`

*Add consistent mass contribution to left-hand side.*
- `virtual void MassToRHS (real_t coef=1)`

*Add consistent mass contribution to right-hand side.*
- `void setLumpedMass ()`

*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
- `void setMass ()`

*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
- `virtual void Stiffness (real_t coef=1)`

*Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- `virtual void StiffnessToRHS (real_t coef=1)`

*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- `void setDilatation ()`

*Add dilatation matrix to left and/or right-hand side taking into account time.*
- `void setDeviator ()`

*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
- `void setStiffness ()`

*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- `void updateBC (const Element &el, const Vect< T_ > &bc)`

*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< T_ > &bc)`

*Update Right-Hand side by taking into account essential boundary conditions.*
- `void DiagBC (int dof_type=NODE.DOF, int dof=0)`

*Update element matrix to impose bc by diagonalization technique.*
- `void LocalNodeVector (Vect< T_ > &b)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be, int dof)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< T_ > &b, LocalVect< T_, NSE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< T_ > &b, int dof_type=NODE.FIELD, int flag=0)`

*Localize Element Vector.*

- void [SideVector](#) (const [Vect](#)< T\_ > &b)  
*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*



- void **DGElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **AxbAssembly** (const **Element** &el, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void **AxbAssembly** (const **Side** &sd, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- void **setInitialSolution** (const **Vect**< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t **setMaterialProperty** (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void **setMesh** (**Mesh** &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- **Mesh** & **getMesh** () const  
*Return reference to **Mesh** instance.*
- **LinearSolver**< T\_ > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int **SolveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_, NEE\_ > **eMat**  
***LocalMatrix** instance containing local matrix associated to current element.*
- **LocalMatrix**< T\_, NSE\_, NSE\_ > **sMat**  
***LocalMatrix** instance containing local matrix associated to current side.*
- **LocalVect**< T\_, NEE\_ > **ePrev**  
***LocalVect** instance containing local vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRHS**  
***LocalVect** instance containing local right-hand side vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRes**  
***LocalVect** instance containing local residual vector associated to current element.*
- **LocalVect**< T\_, NSE\_ > **sRHS**  
***LocalVect** instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **Young** (const real\_t &E)  
*Set (constant) Young modulus.*
- void **Young** (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void **Poisson** (const real\_t &nu)

- *Set (constant) Poisson ratio.*
- void **Poisson** (const string &exp)  
*Set Poisson ratio given by an algebraic expression.*
- void **Density** (const **real\_t** &rho)  
*Set (constant) density.*
- void **Density** (const string &exp)  
*Set density given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.20.1 Detailed Description

To build element equations for 2-D linearized elasticity using 4-node quadrilaterals.

This class enables building finite element arrays for linearized isotropic elasticity problem in 2-D domains using 4-Node quadrilaterals.

Unilateral contact is handled using a penalty function. Note that members calculating element arrays have as an argument a real coef that is multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.20.2 Constructor & Destructor Documentation

**Elas2DQ4** ( )

Default Constructor.

Constructs an empty equation.

**Elas2DQ4** ( const **Element** \* *element*, const **Vect**< **real\_t** > & *u*, const **real\_t** & *time* = 0. )

Constructor using element and previous time data.

Parameters

|    |                |                                                                |
|----|----------------|----------------------------------------------------------------|
| in | <i>element</i> | Pointer to element                                             |
| in | <i>u</i>       | <b>Vect</b> instance containing solution at previous time step |
| in | <i>time</i>    | Current time value [Default: 0]                                |

**Elas2DQ4** ( const **Side** \* *side*, const **Vect**< **real\_t** > & *u*, const **real\_t** & *time* = 0. )

Constructor using side and previous time data.

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>side</i> | Pointer to side                                                |
| in | <i>u</i>    | <b>Vect</b> instance containing solution at previous time step |
| in | <i>time</i> | Current time value [Default: 0]                                |

### 7.20.3 Member Function Documentation

**void PlaneStrain** ( **real\_t** *E*, **real\_t** *nu* )

Set plane strain hypothesis by giving values of Young's modulus and Poisson ratio.

Parameters

|    |       |                 |
|----|-------|-----------------|
| in | $E$   | Young's modulus |
| in | $\nu$ | Poisson ratio   |

**void PlaneStress ( real\_t  $E$ , real\_t  $\nu$  )**

Set plane stress hypothesis by giving values of Young's modulus and Poisson ratio.

Parameters

|    |       |                 |
|----|-------|-----------------|
| in | $E$   | Young's modulus |
| in | $\nu$ | Poisson ratio   |

**void DilatationToRHS ( real\_t  $coef = 1.$  )** [virtual]

Add element dilatational contribution to right hand side after multiplication by  $coef$  [Default: 1].

To use for explicit formulations

Reimplemented from [Equa.Solid< real\\_t, 4, 8, 2, 4 >](#).

**void BodyRHS ( UserData< real\_t > &  $ud$  )**

Add body right-hand side term to right hand side after multiplication by  $coef$

Body forces are deduced from [UserData](#) instance  $ud$

**void BodyRHS ( const Vect< real\_t > &  $bf$ , int  $opt = GLOBAL\_ARRAY$  )**

Add body right-hand side term to right hand side.

Parameters

|    |       |                                                                                                                             |
|----|-------|-----------------------------------------------------------------------------------------------------------------------------|
| in | $bf$  | Vector containing source at element nodes (DOF by DOF).                                                                     |
| in | $opt$ | Vector is local (LOCAL_ARRAY) with size 8 or global (GLOBAL_ARRAY) with size = Total number of DOF [Default: GLOBAL_ARRAY]. |

**void BoundaryRHS ( UserData< real\_t > &  $ud$  )**

Add boundary right-hand side term to right hand side after multiplication by  $coef$

Boundary forces are deduced from [UserData](#) instance  $ud$

**void BoundaryRHS ( const Vect< real\_t > &  $sf$  )**

Add boundary right-hand side term to right hand side.

Parameters

|    |      |                                                         |
|----|------|---------------------------------------------------------|
| in | $sf$ | Vector containing source at element nodes (DOF by DOF). |
|----|------|---------------------------------------------------------|

Warning

The vector  $sf$  is sidewise constant, *i.e.* its size is twice the number of sides.

**int SignoriniContact ( UserData< real\_t > &  $ud$ , real\_t  $coef = 1.e07$  )**

Penalty Signorini contact side contribution to matrix and right-hand side.

Parameters

|    |             |                                                                      |
|----|-------------|----------------------------------------------------------------------|
| in | <i>ud</i>   | <a href="#">UserData</a> instance defining contact data              |
| in | <i>coef</i> | Penalty value by which the added term is multiplied [Default: 1.e07] |

Returns

0 if no contact was realized on this side, 1 otherwise

**void Strain ( LocalVect< real\_t, 3 > & *eps* )**

Calculate strains at element barycenter.

Parameters

|     |            |                                      |
|-----|------------|--------------------------------------|
| out | <i>eps</i> | Vector containing strains in element |
|-----|------------|--------------------------------------|

**void Stress ( LocalVect< real\_t, 3 > & *s*, real\_t & *vm* )**

Calculate principal stresses and Von-Mises stress at element barycenter.

Parameters

|     |           |                                                                    |
|-----|-----------|--------------------------------------------------------------------|
| out | <i>s</i>  | <a href="#">LocalVect</a> containing principal stresses in element |
| out | <i>vm</i> | Value of Von-Mises stress in element                               |

**void Stress ( LocalVect< real\_t, 3 > & *sigma*, LocalVect< real\_t, 3 > & *s*, real\_t & *vm* )**

Calculate principal stresses and Von-Mises stress at element barycenter.

Parameters

|     |              |                                                 |
|-----|--------------|-------------------------------------------------|
| out | <i>sigma</i> | Vector containing principal stresses in element |
| out | <i>s</i>     | Vector containing principal stresses in element |
| out | <i>vm</i>    | Value of Von-Mises stress in element            |

**virtual void MassToLHS ( real\_t *coef* = 1 )** [virtual], [inherited]

Add consistent mass contribution to left-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the matrix before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|

**virtual void MassToRHS ( real\_t *coef* = 1 )** [virtual], [inherited]

Add consistent mass contribution to right-hand side.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>coef</i> | coefficient to multiply by the vector before adding [Default: 1] |
|----|-------------|------------------------------------------------------------------|

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

## Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.



## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

## Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > &  $b$  )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \*  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|                 |     |                                                               |
|-----------------|-----|---------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----------------|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|  |     |                                                               |
|--|-----|---------------------------------------------------------------|
|  | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|--|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|         |     |                                                                                 |
|---------|-----|---------------------------------------------------------------------------------|
| in      | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in      | $b$ | Vector containing right-hand side                                               |
| in, out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

#### 7.20.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

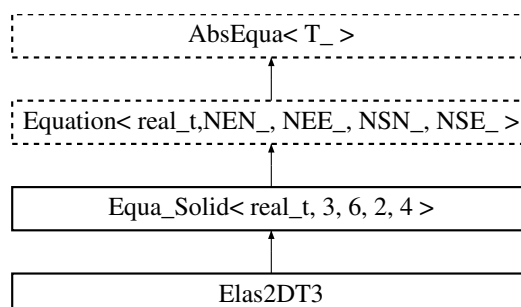
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.21 Elas2DT3 Class Reference

To build element equations for 2-D linearized elasticity using 3-node triangles.

Inheritance diagram for Elas2DT3:



#### Public Member Functions

- [Elas2DT3](#) ()  
*Default Constructor.*
- [Elas2DT3](#) ([Mesh](#) &ms)  
*Constructor using [Mesh](#) data.*
- [Elas2DT3](#) (const [Element](#) \*el)  
*Constructor using element data.*
- [Elas2DT3](#) (const [Side](#) \*sd)  
*Constructor using side data.*
- [Elas2DT3](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)  
*Constructor using element, previous time solution  $u$  and time value.*
- [Elas2DT3](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time, [real\\_t](#) deltat, int scheme)  
*Constructor for an element (transient case) with specification of time integration scheme.*
- [Elas2DT3](#) (const [Side](#) \*sd, const [Vect](#)< [real\\_t](#) > &u, [real\\_t](#) time=0.)

- Constructor using *side*, previous time solution *u* and time value.

  - `Elas2DT3 (const Side *sd, const Vect< real.t > &u, real.t time, real.t deltat, int scheme)`

Constructor for a *side* (transient case) with specification of time integration scheme.
- `~Elas2DT3 ()`

Destructor.
- `void Media (real.t E, real.t nu, real.t rho)`

Set media properties.
- `void PlaneStrain ()`

Set plane strain hypothesis.
- `void PlaneStrain (real.t E, real.t nu)`

Set plane strain hypothesis by giving values of Young's modulus *E* and Poisson ratio *nu*
- `void PlaneStress ()`

Set plane stress hypothesis.
- `void PlaneStress (real.t E, real.t nu)`

Set plane stress hypothesis by giving values of Young's modulus *E* and Poisson ratio *nu*
- `void LMassToLHS (real.t coef=1.)`

Add element lumped mass contribution to matrix after multiplication by *coef*
- `void LMassToRHS (real.t coef=1.)`

Add element lumped mass contribution to right-hand side after multiplication by *coef*
- `void LMass (real.t coef=1.)`

Add element lumped mass contribution to matrix and right-hand side after multiplication by *coef*
- `void MassToLHS (real.t coef=1.)`

Add element consistent mass contribution to matrix after multiplication by *coef*
- `void MassToRHS (real.t coef=1.)`

Add element consistent mass contribution to right-hand side after multiplication by *coef*
- `void Mass (real.t coef=1.)`

Add element consistent mass contribution to matrix and right-hand side after multiplication by *coef*
- `void Deviator (real.t coef=1.)`

Add element deviatoric matrix to left-hand side after multiplication by *coef*
- `void DeviatorToRHS (real.t coef=1.)`

Add element deviatoric contribution to right-hand side after multiplication by *coef*
- `void Dilatation (real.t coef=1.)`

Add element dilatational contribution to left-hand side after multiplication by *coef*
- `void DilatationToRHS (real.t coef=1.)`

Add element dilatational contribution to right-hand side after multiplication by *coef*
- `void BodyRHS (UserData< real.t > &ud)`

Add body right-hand side term to right-hand side after multiplication by *coef*
- `void BodyRHS (const Vect< real.t > &f, int opt=GLOBAL_ARRAY)`

Add body right-hand side term to right hand side.
- `void BoundaryRHS (UserData< real.t > &ud)`

Add boundary right-hand side term to right hand side after multiplication by *coef*
- `void BoundaryRHS (const Vect< real.t > &f)`

Add boundary right-hand side term to right hand side.
- `int SignoriniContact (UserData< real.t > &ud, real.t coef=1.e07)`

Penalty Signorini contact side contribution to matrix and right-hand side.
- `int SignoriniContact (Vect< real.t > &f, real.t coef=1.e07)`

- Penalty Signorini contact side contribution to matrix and right-hand side.*

  - void [Reaction](#) ([Vect](#)< [real\\_t](#) > &r)

*Calculate reactions.*
- void [ContactPressure](#) (const [Vect](#)< [real\\_t](#) > &f, [real\\_t](#) penal, [Point](#)< [real\\_t](#) > &p)

*Calculate contact pressure.*
- void [Strain](#) ([Vect](#)< [real\\_t](#) > &eps)

*Calculate strains in element.*
- void [Stress](#) ([Vect](#)< [real\\_t](#) > &s, [real\\_t](#) &vm)

*Calculate principal stresses and Von-Mises stress in element.*
- void [Periodic](#) ([real\\_t](#) coef=1.e20)

*Add contribution of periodic boundary condition (by a penalty technique).*
- void [setLumpedMass](#) ()

*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
- void [setMass](#) ()

*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void [Stiffness](#) ([real\\_t](#) coef=1)

*Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void [StiffnessToRHS](#) ([real\\_t](#) coef=1)

*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- void [setDilatation](#) ()

*Add dilatation matrix to left and/or right-hand side taking into account time.*
- void [setDeviator](#) ()

*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
- void [setStiffness](#) ()

*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< [T\\_](#) > &bc)

*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [T\\_](#) > &bc)

*Update Right-Hand side by taking into account essential boundary conditions.*
- void [DiagBC](#) (int dof\_type=NODE.DOF, int dof=0)

*Update element matrix to impose bc by diagonalization technique.*
- void [LocalNodeVector](#) ([Vect](#)< [T\\_](#) > &b)

*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [T\\_](#) > &b, [LocalVect](#)< [T\\_](#), [NEE\\_](#) > &be)

*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [T\\_](#) > &b, [LocalVect](#)< [T\\_](#), [NEN\\_](#) > &be, int dof)

*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [T\\_](#) > &b, [LocalVect](#)< [T\\_](#), [NEN\\_](#) > &be)

*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementSideVector](#) (const [Vect](#)< [T\\_](#) > &b, [LocalVect](#)< [T\\_](#), [NSE\\_](#) > &be)

*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementVector](#) (const [Vect](#)< [T\\_](#) > &b, int dof\_type=NODE.FIELD, int flag=0)

*Localize [Element](#) Vector.*
- void [SideVector](#) (const [Vect](#)< [T\\_](#) > &b)

*Localize [Side](#) Vector.*



- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) (Matrix< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScVect< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) (BMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (TrMatrix< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (Vect< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) (PETScMatrix< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) (PETScVect< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) (Matrix< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (Vect< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) (Matrix< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkSMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SpMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (TrMatrix< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

- void **AxbAssembly** (const **Element** &el, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void **AxbAssembly** (const **Side** &sd, const **Vect**< T\_ > &x, **Vect**< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- void **setInitialSolution** (const **Vect**< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t **setMaterialProperty** (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void **setMesh** (**Mesh** &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- **Mesh** & **getMesh** () const  
*Return reference to **Mesh** instance.*
- **LinearSolver**< T\_ > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int **SolveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_ > **eMat**  
***LocalMatrix** instance containing local matrix associated to current element.*
- **LocalMatrix**< T\_, NSE\_ > **sMat**  
***LocalMatrix** instance containing local matrix associated to current side.*
- **LocalVect**< T\_, NEE\_ > **ePrev**  
***LocalVect** instance containing local vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRHS**  
***LocalVect** instance containing local right-hand side vector associated to current element.*
- **LocalVect**< T\_, NEE\_ > **eRes**  
***LocalVect** instance containing local residual vector associated to current element.*
- **LocalVect**< T\_, NSE\_ > **sRHS**  
***LocalVect** instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **Young** (const real\_t &E)  
*Set (constant) Young modulus.*
- void **Young** (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void **Poisson** (const real\_t &nu)  
*Set (constant) Poisson ratio.*
- void **Poisson** (const string &exp)

- void **Density** (const **real\_t** &rho)  
*Set Poisson ratio given by an algebraic expression.*
- void **Density** (const string &exp)  
*Set (constant) density.*
- void **setMaterial** ()  
*Set density given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.21.1 Detailed Description

To build element equations for 2-D linearized elasticity using 3-node triangles.

This class enables building finite element arrays for linearized isotropic elasticity problem in 2-D domains using 3-Node triangles.

Unilateral contact is handled using a penalty function. Note that members calculating element arrays have as an argument a real coef that is multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.21.2 Constructor & Destructor Documentation

#### **Elas2DT3 ( )**

Default Constructor.

Constructs an empty equation.

#### **Elas2DT3 ( Mesh & ms )**

Constructor using **Mesh** data.

Parameters

|           |           |                      |
|-----------|-----------|----------------------|
| <b>in</b> | <b>ms</b> | <b>Mesh</b> instance |
|-----------|-----------|----------------------|

#### **Elas2DT3 ( const Element \* el )**

Constructor using element data.

Parameters

|           |                                    |
|-----------|------------------------------------|
| <b>el</b> | Pointer to <b>Element</b> instance |
|-----------|------------------------------------|

#### **Elas2DT3 ( const Side \* sd )**

Constructor using side data.

Parameters

|           |                                 |
|-----------|---------------------------------|
| <b>sd</b> | Pointer to <b>Side</b> instance |
|-----------|---------------------------------|

#### **Elas2DT3 ( const Element \* el, const Vect< real\_t > & u, real\_t time = 0. )**

Constructor using element, previous time solution u and time value.

Parameters

|    |             |                                                                             |
|----|-------------|-----------------------------------------------------------------------------|
| in | <i>el</i>   | Pointer to element.                                                         |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | <i>time</i> | Current time value [Default: 0].                                            |

**Elas2DT3 ( const Element \* *el*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for an element (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                                                                                                                                                                                                                      |
|----|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>     | Pointer to element.                                                                                                                                                                                                                                                  |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step.                                                                                                                                                                                          |
| in | <i>time</i>   | Current time value.                                                                                                                                                                                                                                                  |
| in | <i>deltat</i> | Time step.                                                                                                                                                                                                                                                           |
| in | <i>scheme</i> | Time Integration Scheme: To be chosen among the enumerated values: <ul style="list-style-type: none"> <li>• FORWARD_EULER: Forward Euler scheme</li> <li>• BACKWARD_EULER: Backward Euler scheme,</li> <li>• CRANK_NICOLSON: Crank-Nicolson Euler scheme.</li> </ul> |

**Elas2DT3 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time* = 0. )**

Constructor using side, previous time solution u and time value.

Parameters

|    |             |                                                                             |
|----|-------------|-----------------------------------------------------------------------------|
| in | <i>sd</i>   | Pointer to side.                                                            |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | <i>time</i> | Current time value [Default: 0].                                            |

**Elas2DT3 ( const Side \* *sd*, const Vect< real.t > & *u*, real.t *time*, real.t *deltat*, int *scheme* )**

Constructor for a side (transient case) with specification of time integration scheme.

Parameters

|    |               |                                                                             |
|----|---------------|-----------------------------------------------------------------------------|
| in | <i>sd</i>     | Pointer to side.                                                            |
| in | <i>u</i>      | <a href="#">Vect</a> instance that contains solution at previous time step. |
| in | <i>time</i>   | Current time value [Default: 0].                                            |
| in | <i>deltat</i> | Time step.                                                                  |
| in | <i>scheme</i> | Time Integration Scheme                                                     |

### 7.21.3 Member Function Documentation

**void Media ( real.t *E*, real.t *nu*, real.t *rho* )**

Set media properties.

Useful to override material properties deduced from mesh file.

**void LMassToLHS ( *real\_t coef* = 1. )** [virtual]

Add element lumped mass contribution to matrix after multiplication by *coef*

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void LMassToRHS ( real\_t coef = 1. )** [virtual]

Add element lumped mass contribution to right-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void LMass ( real\_t coef = 1. )** [virtual]

Add element lumped mass contribution to matrix and right-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void MassToLHS ( real\_t coef = 1. )** [virtual]

Add element consistent mass contribution to matrix after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void MassToRHS ( real\_t coef = 1. )** [virtual]

Add element consistent mass contribution to right-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void Mass ( real\_t coef = 1. )** [virtual]

Add element consistent mass contribution to matrix and right-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void Deviator ( real\_t coef = 1. )** [virtual]

Add element deviatoric matrix to left-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void DeviatorToRHS ( real\_t coef = 1. ) [virtual]**

Add element deviatoric contribution to right-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void Dilatation ( real\_t coef = 1. ) [virtual]**

Add element dilatational contribution to left-hand side after multiplication by coef

Parameters

|           |             |                                                     |
|-----------|-------------|-----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1]. |
|-----------|-------------|-----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void DilatationToRHS ( real\_t coef = 1. ) [virtual]**

Add element dilatational contribution to right-hand side after multiplication by coef

To use for explicit formulations

Parameters

|           |             |                                                    |
|-----------|-------------|----------------------------------------------------|
| <b>in</b> | <i>coef</i> | Coefficient to multiply by added term [Default: 1] |
|-----------|-------------|----------------------------------------------------|

Reimplemented from [Equa.Solid< real\\_t, 3, 6, 2, 4 >](#).

**void BodyRHS ( UserData< real\_t > & ud )**

Add body right-hand side term to right-hand side after multiplication by coef

Body forces are deduced from [UserData](#) instance ud

**void BodyRHS ( const Vect< real\_t > & f, int opt = GLOBAL\_ARRAY )**

Add body right-hand side term to right hand side.

Parameters

|           |            |                                                                                                                               |
|-----------|------------|-------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>f</i>   | Vector containing source at element nodes (DOF by DOF)                                                                        |
| <b>in</b> | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 6 or global (GLOBAL_ARRAY) with size = Number of element DOF [Default: GLOBAL_ARRAY]. |

**void BoundaryRHS ( UserData< real\_t > & ud )**

Add boundary right-hand side term to right hand side after multiplication by coef

Parameters

|           |           |                                                            |
|-----------|-----------|------------------------------------------------------------|
| <b>in</b> | <i>ud</i> | <a href="#">UserData</a> instance defining boundary forces |
|-----------|-----------|------------------------------------------------------------|

**void BoundaryRHS ( const Vect< real\_t > & f )**

Add boundary right-hand side term to right hand side.

Parameters

|                 |                |                                                                                  |
|-----------------|----------------|----------------------------------------------------------------------------------|
| <code>in</code> | <code>f</code> | <a href="#">Vect</a> instance that contains constant traction to impose to side. |
|-----------------|----------------|----------------------------------------------------------------------------------|

**int SignoriniContact ( UserData< real\_t > &ud, real\_t coef = 1.e07 )**

Penalty Signorini contact side contribution to matrix and right-hand side.

Parameters

|                 |                   |                                                                      |
|-----------------|-------------------|----------------------------------------------------------------------|
| <code>in</code> | <code>ud</code>   | <a href="#">UserData</a> instance defining contact data              |
| <code>in</code> | <code>coef</code> | Penalty value by which the added term is multiplied [Default: 1.e07] |

Returns

= 0 if no contact is achieved on this side, 1 otherwise

**int SignoriniContact ( Vect< real\_t > &f, real\_t coef = 1.e07 )**

Penalty Signorini contact side contribution to matrix and right-hand side.

Parameters

|                 |                   |                                                                      |
|-----------------|-------------------|----------------------------------------------------------------------|
| <code>in</code> | <code>f</code>    | <a href="#">Vect</a> instance that contains contact data             |
| <code>in</code> | <code>coef</code> | Penalty value by which the added term is multiplied [Default: 1.e07] |

Returns

= 0 if no contact is achieved on this side, 1 otherwise

**void Reaction ( Vect< real\_t > &r )**

Calculate reactions.

This function can be invoked in postprocessing

Parameters

|                 |                |                      |
|-----------------|----------------|----------------------|
| <code>in</code> | <code>r</code> | Reaction on the side |
|-----------------|----------------|----------------------|

**void ContactPressure ( const Vect< real\_t > &f, real\_t penal, Point< real\_t > &p )**

Calculate contact pressure.

This function can be invoked in postprocessing

Parameters

|                  |                    |                                                             |
|------------------|--------------------|-------------------------------------------------------------|
| <code>in</code>  | <code>f</code>     |                                                             |
| <code>in</code>  | <code>penal</code> | Penalty parameter that was used to impose contact condition |
| <code>out</code> | <code>p</code>     | Contact pressure                                            |

**void Strain ( Vect< real\_t > &eps )**

Calculate strains in element.

This function can be invoked in postprocessing.



**void Stress ( Vect< real\_t > & *s*, real\_t & *vm* )**

Calculate principal stresses and Von-Mises stress in element.

Parameters

|           |           |                                                                   |
|-----------|-----------|-------------------------------------------------------------------|
| <b>in</b> | <i>s</i>  | vector of principal stresses                                      |
| <b>in</b> | <i>vm</i> | Von-Mises stress. This function can be invoked in postprocessing. |

**void Periodic ( real\_t coef = 1.e20 )**

Add contribution of periodic boundary condition (by a penalty technique).

Boundary nodes where periodic boundary conditions are to be imposed must have codes equal to PERIODIC.A on one side and PERIODIC.B on the opposite side.

Parameters

|           |             |                                             |
|-----------|-------------|---------------------------------------------|
| <b>in</b> | <i>coef</i> | Value of penalty parameter [Default: 1.e20] |
|-----------|-------------|---------------------------------------------|

**void updateBC ( const Element & el, const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>el</i> | Reference to current element instance           |
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |
|-----------|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|           |                 |                                                                                                                                                                                                                                                                           |
|-----------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE_FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT_FIELD, DOFs are supported by elements</li> <li>• SIDE_FIELD, DOFs are supported by sides</li> </ul> |
|-----------|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|           |            |                                                                                                                                                                                   |
|-----------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>dof</i> | DOF setting: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF No. <i>dof</i> is handled in the system</li> </ul> |
|-----------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|           |          |                                                                                                                                                                                                                  |
|-----------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <i>ePrev</i> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|-----------|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|            |           |                                                                             |
|------------|-----------|-----------------------------------------------------------------------------|
| <i>in</i>  | <i>b</i>  | Global vector to be localized.                                              |
| <i>out</i> | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|            |            |                                                                             |
|------------|------------|-----------------------------------------------------------------------------|
| <i>in</i>  | <i>b</i>   | Global vector to be localized.                                              |
| <i>out</i> | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| <i>in</i>  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> <p>The resulting local vector can be accessed by attribute <i>ePrev</i>.</p>                            |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                     |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> <p>The resulting local vector can be accessed by attribute <i>ePrev</i>.</p> |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|  |     |                            |
|--|-----|----------------------------|
|  | $A$ | Reference to global matrix |
|--|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|  |     |                                            |
|--|-----|--------------------------------------------|
|  | $b$ | Reference to global right-hand side vector |
|--|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|          |                                                               |
|----------|---------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|           |           |                                                               |
|-----------|-----------|---------------------------------------------------------------|
| <i>in</i> | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| <i>in</i> | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |

|     |          |                                                       |
|-----|----------|-------------------------------------------------------|
| out | <i>b</i> | Global vector to add ( <a href="#">Vect</a> instance) |
|-----|----------|-------------------------------------------------------|

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

### 7.21.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

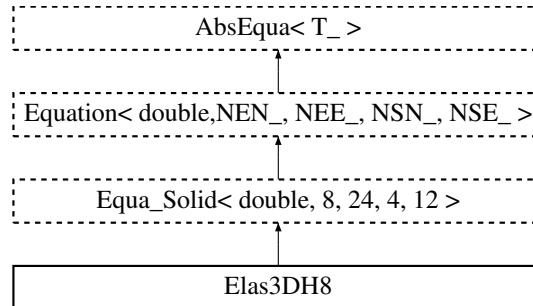
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.22 Elas3DH8 Class Reference

To build element equations for 3-D linearized elasticity using 8-node hexahedra.

Inheritance diagram for Elas3DH8:



### Public Member Functions

- **Elas3DH8** ()  
*Default Constructor.*
- **Elas3DH8** (const **Element** \*el)  
*Constructor using element data.*
- **Elas3DH8** (const **Side** \*sd)  
*Constructor using side data.*
- **Elas3DH8** (const **Element** \*element, const **Vect**< **real\_t** > &u, const **real\_t** &time=0.)  
*Constructor using element, previous time solution u and time value.*
- **Elas3DH8** (const **Side** \*side, const **Vect**< **real\_t** > &u, const **real\_t** &time=0.)  
*Constructor using side, previous time solution u and time value.*
- **~Elas3DH8** ()  
*Destructor.*
- void **LMassToLHS** (**real\_t** coef=1.)  
*Add element lumped mass contribution to matrix after multiplication by coef.*
- void **LMassToRHS** (**real\_t** coef=1.)  
*Add element lumped mass contribution to right-hand side after multiplication by coef.*
- void **LMass** (**real\_t** coef)  
*Add element lumped mass contribution to right-hand and left-hand sides after multiplication by coef.*
- void **Mass** (**real\_t** coef=1.)  
*Add element lumped mass contribution to matrix and right-hand side after multiplication by coef.*
- void **Deviator** (**real\_t** coef=1.)  
*Add element deviatoric matrix to left-hand side after multiplication by coef.*
- void **DeviatorToRHS** (**real\_t** coef=1.)  
*Add element deviatoric matrix to right-hand side after multiplication by coef.*
- void **Dilatation** (**real\_t** coef=1.)  
*Add element dilatational contribution to left hand-side after multiplication by coef.*
- void **DilatationToRHS** (**real\_t** coef=1.)  
*Add element dilatational contribution to right hand-side after multiplication by coef.*
- void **BodyRHS** (**UserData**< **real\_t** > &ud)  
*Add body right-hand side term to right hand side.*

- void **BoundaryRHS** (const **Vect**< **real\_t** > &f)  
*Add boundary right-hand side term to right hand side.*
- void **BodyRHS** (const **Vect**< **real\_t** > &bf, int opt=**LOCAL\_ARRAY**)  
*Add body right-hand side term to right hand side.*
- virtual void **MassToLHS** (**real\_t** coef=1)  
*Add consistent mass contribution to left-hand side.*
- virtual void **MassToRHS** (**real\_t** coef=1)  
*Add consistent mass contribution to right-hand side.*
- void **setLumpedMass** ()  
*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
- void **setMass** ()  
*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void **Stiffness** (**real\_t** coef=1)  
*Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void **StiffnessToRHS** (**real\_t** coef=1)  
*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- void **setDilatation** ()  
*Add dilatation matrix to left and/or right-hand side taking into account time.*
- void **setDeviator** ()  
*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
- void **setStiffness** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=**NODE\_DOF**, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, **NEE\_** > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, **NEN\_** > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, **NEN\_** > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, **NSE\_** > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=**NODE\_FIELD**, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()

- Localize coordinates of side nodes.*

  - void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)

*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)

*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)

*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)

*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)

*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)

*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)

- Assemble product of side matrix by side vector into global vector.*
  - `size_t getNbNodes () const`  
*Return number of element nodes.*
  - `size_t getNbEq () const`  
*Return number of element equations.*
  - `void setInitialSolution (const Vect< T_ > &u)`  
*Set initial solution (previous time step)*
  - `real_t setMaterialProperty (const string &exp, const string &prop)`  
*Define a material property by an algebraic expression.*
  - `void setMesh (Mesh &m)`  
*Define mesh and renumber DOFs after removing imposed ones.*
  - `Mesh & getMesh () const`  
*Return reference to Mesh instance.*
  - `LinearSolver< T_ > & getLinearSolver ()`  
*Return reference to linear solver instance.*
  - `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`  
*Choose solver for the linear system.*
  - `int SolveLinearSystem (Matrix< T_ > *A, Vect< T_ > &b, Vect< T_ > &x)`  
*Solve the linear system.*

## Public Attributes

- `LocalMatrix< T_, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< T_, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< T_, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< T_, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< T_, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< T_, NSE_ > sRHS`  
*LocalVect instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- `void Young (const real_t &E)`  
*Set (constant) Young modulus.*
- `void Young (const string &exp)`  
*Set Young modulus given by an algebraic expression.*
- `void Poisson (const real_t &nu)`  
*Set (constant) Poisson ratio.*
- `void Poisson (const string &exp)`  
*Set Poisson ratio given by an algebraic expression.*
- `void Density (const real_t &rho)`  
*Set (constant) density.*

- void **Density** (const string &exp)  
*Set density given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.22.1 Detailed Description

To build element equations for 3-D linearized elasticity using 8-node hexahedra.

This class enables building finite element arrays for linearized isotropic elasticity problem in 3-D domains using 8-Node hexahedra.

Note that members calculating element arrays have as an argument a double `coef` that is multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.22.2 Constructor & Destructor Documentation

**Elas3DH8** ( )

Default Constructor.

Constructs an empty equation.

### 7.22.3 Member Function Documentation

**void BodyRHS** ( **UserData**< **real\_t** > &*ud* )

Add body right-hand side term to right hand side.

Body forces are deduced from **UserData** instance *ud*.

**void BoundaryRHS** ( const **Vect**< **real\_t** > &*f* )

Add boundary right-hand side term to right hand side.

Parameters

|           |          |                                                      |
|-----------|----------|------------------------------------------------------|
| <i>in</i> | <i>f</i> | Vector containing traction (boundary force) at sides |
|-----------|----------|------------------------------------------------------|

**void BodyRHS** ( const **Vect**< **real\_t** > &*bf*, int *opt* = **LOCAL\_ARRAY** )

Add body right-hand side term to right hand side.

Parameters

|           |            |                                                                                                                          |
|-----------|------------|--------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>bf</i>  | Vector containing source at element nodes (DOF by DOF).                                                                  |
| <i>in</i> | <i>opt</i> | Vector is local ( <b>LOCAL_ARRAY</b> ) with size 24 or global ( <b>GLOBAL_ARRAY</b> ) with size = Number of element DOF. |

**virtual void MassToLHS** ( **real\_t** *coef* = 1 ) [virtual], [inherited]

Add consistent mass contribution to left-hand side.



Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the matrix before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

**virtual void MassToRHS ( `real_t coef = 1` )** [virtual], [inherited]

Add consistent mass contribution to right-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

**void updateBC ( `const Element & el`, `const Vect< T_ > & bc` )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>el</code> | Reference to current element instance           |
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |

**void updateBC ( `const Vect< T_ > & bc` )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |
|-----------------|-----------------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( `int dof_type = NODE_DOF`, `int dof = 0` )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|                 |                       |                                                                                                                                                                                                                                                                                                                  |
|-----------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>dof_type</code> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| <code>in</code> | <code>dof</code>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( `Vect< T_ > & b` )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                          |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute ePrev. This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be*, int *dof* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer *\_theSide*

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array *\_x[0]*, *\_x[1]*, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real\\_t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                               |
|---|---------------------------------------------------------------|
| A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|---|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.



Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

## 7.22.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

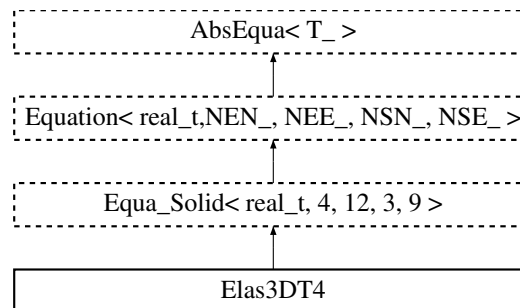
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.23 Elas3DT4 Class Reference

To build element equations for 3-D linearized elasticity using 4-node tetrahedra.

Inheritance diagram for Elas3DT4:



## Public Member Functions

- [Elas3DT4](#) ()  
*Default Constructor.*
- [Elas3DT4](#) (const [Element](#) \*el)  
*Constructor using element data.*
- [Elas3DT4](#) (const [Side](#) \*sd)  
*Constructor using side data.*
- [Elas3DT4](#) (const [Element](#) \*element, const [Vect](#)< [real\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using element and previous time data.*
- [Elas3DT4](#) (const [Side](#) \*side, const [Vect](#)< [real\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using side and previous time data.*
- [~Elas3DT4](#) ()  
*Destructor.*
- void [Media](#) ([real\\_t](#) E, [real\\_t](#) nu, [real\\_t](#) rho)  
*Set Media properties.*
- void [LMassToLHS](#) ([real\\_t](#) coef=1)  
*Add element lumped mass contribution to matrix after multiplication by coef.*
- void [LMassToRHS](#) ([real\\_t](#) coef=1)  
*Add element lumped mass contribution to right-hand side after multiplication by coef.*

- void **LMass** (**real\_t** coef)  
*Add element lumped mass contribution to matrix and right-hand side after multiplication by coef.*
- void **Deviator** (**real\_t** coef=1.)  
*Add element deviatoric matrix to left hand-side after multiplication by coef.*
- void **DeviatorToRHS** (**real\_t** coef=1.)  
*Add element deviatoric matrix to right hand-side after multiplication by coef.*
- void **Dilatation** (**real\_t** coef=1.)  
*Add element dilatational contribution to left-hand side after multiplication by coef.*
- void **DilatationToRHS** (**real\_t** coef=1.)  
*Add element dilatational contribution to right-hand side after multiplication by coef.*
- void **BodyRHS** (**UserData**< **real\_t** > &ud)  
*Add body right-hand side term to right hand side after multiplication by coef.*
- void **BodyRHS** (const **Vect**< **real\_t** > &f, int opt=LOCAL\_ARRAY)  
*Add body right-hand side term to right hand side.*
- void **BoundaryRHS** (const **Vect**< **real\_t** > &f)  
*Add boundary right-hand side term to right hand side.*
- void **buildEigen** (**SkSMatrix**< **real\_t** > &K, **Vect**< **real\_t** > &M)  
*Build global stiffness and mass matrices for the eigen system.*
- virtual void **MassToLHS** (**real\_t** coef=1)  
*Add consistent mass contribution to left-hand side.*
- virtual void **MassToRHS** (**real\_t** coef=1)  
*Add consistent mass contribution to right-hand side.*
- void **setLumpedMass** ()  
*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
- void **setMass** ()  
*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void **Mass** (**real\_t** coef=1)  
*Add consistent mass matrix to left-hand side after multiplication by coef [Default: 1].*
- virtual void **Stiffness** (**real\_t** coef=1)  
*Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void **StiffnessToRHS** (**real\_t** coef=1)  
*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- void **setDilatation** ()  
*Add dilatation matrix to left and/or right-hand side taking into account time.*
- void **setDeviator** ()  
*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
- void **setStiffness** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)

- Localize [Element](#) Vector from a [Vect](#) instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEE\_ > &be)
- Localize [Element](#) Vector from a [Vect](#) instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be, int dof)
- Localize [Element](#) Vector from a [Vect](#) instance.*

  - void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be)
- Localize [Element](#) Vector from a [Vect](#) instance.*

  - void [ElementSideVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NSE\_ > &be)
- Localize [Element](#) Vector from a [Vect](#) instance.*

  - void [ElementVector](#) (const [Vect](#)< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)
- Localize [Element](#) Vector.*

  - void [SideVector](#) (const [Vect](#)< T\_ > &b)
- Localize [Side](#) Vector.*

  - void [ElementNodeCoordinates](#) ()
- Localize coordinates of element nodes.*

  - void [SideNodeCoordinates](#) ()
- Localize coordinates of side nodes.*

  - void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble element right-hand side vector into global one.*

  - void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble element vector into global one.*

  - void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)
- Assemble side matrix into global one.*

  - void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble side right-hand side vector into global one.*

  - void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)

- *Assemble side (edge or face) matrix into global one.*  
void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- *Assemble side (edge or face) vector into global one.*  
void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- *Assemble product of element matrix by element vector into global vector.*  
void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- *Assemble product of side matrix by side vector into global vector.*  
size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_ > eMat  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > sMat  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > ePrev  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRes  
*[LocalVect](#) instance containing local residual vector associated to current element.*
- [LocalVect](#)< T\_, NSE\_ > sRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void **Young** (const **real\_t** &E)  
*Set (constant) Young modulus.*
- void **Young** (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void **Poisson** (const **real\_t** &nu)  
*Set (constant) Poisson ratio.*
- void **Poisson** (const string &exp)  
*Set Poisson ratio given by an algebraic expression.*
- void **Density** (const **real\_t** &rho)  
*Set (constant) density.*
- void **Density** (const string &exp)  
*Set density given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.23.1 Detailed Description

To build element equations for 3-D linearized elasticity using 4-node tetrahedra.

This class enables building finite element arrays for linearized isotropic elasticity problem in 3-D domains using 4-Node tetrahedra.

### 7.23.2 Member Function Documentation

**void Media ( **real\_t** E, **real\_t** nu, **real\_t** rho )**

Set Media properties.

Parameters

|    |     |                 |
|----|-----|-----------------|
| in | E   | Young's modulus |
| in | nu  | Poisson ratio   |
| in | rho | Density         |

**void BodyRHS ( **UserData**< **real\_t** > &ud )**

Add body right-hand side term to right hand side after multiplication by *coef*.

Body forces are deduced from **UserData** instance *ud*.

**void BodyRHS ( const **Vect**< **real\_t** > &f, int opt = LOCAL\_ARRAY )**

Add body right-hand side term to right hand side.

Parameters

|    |     |                                                                                                        |
|----|-----|--------------------------------------------------------------------------------------------------------|
| in | f   | <b>Vect</b> instance containing source at element nodes (DOF by DOF).                                  |
| in | opt | Vector is local (LOCAL_ARRAY) with size 12 or global (GLOBAL_ARRAY) with size = Number of element DOF. |

**void BoundaryRHS ( const Vect< real\_t > &f )**

Add boundary right-hand side term to right hand side.

Parameters

|                 |                |                                                                                  |
|-----------------|----------------|----------------------------------------------------------------------------------|
| <code>in</code> | <code>f</code> | <a href="#">Vect</a> instance that contains constant traction to impose to side. |
|-----------------|----------------|----------------------------------------------------------------------------------|

**void buildEigen ( SkSMatrix< real\_t > & K, Vect< real\_t > & M )**

Build global stiffness and mass matrices for the eigen system.

Case where the mass matrix is lumped

Parameters

|                 |                |                                        |
|-----------------|----------------|----------------------------------------|
| <code>in</code> | <code>K</code> | Stiffness matrix                       |
| <code>in</code> | <code>M</code> | Vector containing diagonal mass matrix |

**virtual void MassToLHS ( real\_t coef = 1 )** [virtual], [inherited]

Add consistent mass contribution to left-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the matrix before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

**virtual void MassToRHS ( real\_t coef = 1 )** [virtual], [inherited]

Add consistent mass contribution to right-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

**void updateBC ( const Element & el, const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>el</code> | Reference to current element instance           |
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |
|-----------------|-----------------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.



## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the degree of freedom is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

## Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|  |     |                            |
|--|-----|----------------------------|
|  | $A$ | Reference to global matrix |
|--|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|  |     |                                            |
|--|-----|--------------------------------------------|
|  | $b$ | Reference to global right-hand side vector |
|--|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|          |                                                              |
|----------|--------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|           |           |                                                               |
|-----------|-----------|---------------------------------------------------------------|
| <i>in</i> | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| <i>in</i> | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |



|     |          |                                                       |
|-----|----------|-------------------------------------------------------|
| out | <i>b</i> | Global vector to add ( <a href="#">Vect</a> instance) |
|-----|----------|-------------------------------------------------------|

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

### 7.23.3 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.24 Element Class Reference

To store and treat finite element geometric information.

### Public Member Functions

- [Element](#) ()  
*Default constructor.*
- [Element](#) (size\_t label, const string &shape)  
*Constructor initializing label, shape of element.*
- [Element](#) (size\_t label, int shape)  
*Constructor initializing label, shape of element.*
- [Element](#) (size\_t label, const string &shape, int c)  
*Constructor initializing label, shape and code of element.*
- [Element](#) (size\_t label, int shape, int c)  
*Constructor initializing label, shape and code of element.*
- [Element](#) (const [Element](#) &el)  
*Copy constructor.*
- [~Element](#) ()  
*Destructor.*
- void [setLabel](#) (size\_t i)  
*Define label of element.*
- void [setCode](#) (int c)  
*Define code of element.*
- void [setCode](#) (const string &exp, int code)  
*Define code by a boolean algebraic expression invoking coordinates of element nodes.*
- void [Add](#) ([Node](#) \*node)  
*Insert a node at end of list of nodes of element.*
- void [Add](#) ([Node](#) \*node, int n)  
*Insert a node and set its local node number.*
- void [Replace](#) (size\_t label, [Node](#) \*node)  
*Replace a node at a given local label.*
- void [Replace](#) (size\_t label, [Side](#) \*side)  
*Replace a side at a given local label.*
- void [Add](#) ([Side](#) \*sd)  
*Assign Side to Element.*
- void [Add](#) ([Side](#) \*sd, int k)  
*Assign Side to Element with assigned local label.*
- void [Add](#) ([Element](#) \*el)  
*Add a neighbor element.*
- void [set](#) ([Element](#) \*el, int n)  
*Add a neighbor element and set its label.*
- void [setDOF](#) (size\_t i, size\_t dof)  
*Define label of DOF.*
- void [setCode](#) (size\_t dof, int code)  
*Assign code to a DOF.*
- void [setNode](#) (size\_t i, [Node](#) \*node)

*Assign a node given by its pointer as the i-th node of element.*

- void **setNbDOF** (size\_t i)  
*Set number of degrees of freedom of element.*
- void **setFirstDOF** (size\_t i)  
*Set label of first DOF in element.*
- int **getShape** () const  
*Return element shape.*
- size\_t **getLabel** () const  
*Return label of element.*
- size\_t **n** () const  
*Return label of element.*
- int **getCode** () const  
*Return code of element.*
- size\_t **getNbNodes** () const  
*Return number of element nodes.*
- size\_t **getNbVertices** () const  
*Return number of element vertices.*
- size\_t **getNbSides** () const  
*Return number of element sides (Constant version)*
- size\_t **getNbEq** () const  
*Return number of element equations.*
- size\_t **getNbDOF** () const  
*return element nb of DOF*
- size\_t **getDOF** (size\_t i=1) const  
*Return element DOF label.*
- size\_t **getFirstDOF** () const  
*Return element first DOF label.*
- size\_t **getNodeLabel** (size\_t n) const  
*Return global label of node of local label i.*
- size\_t **getSideLabel** (size\_t n) const  
*Return global label of side of local label i.*
- **Node** \* **getPtrNode** (size\_t i) const  
*Return pointer to node of label i (Local labelling).*
- **Node** \* **operator()** (size\_t i) const  
*Operator ().*
- **Side** \* **getPtrSide** (size\_t i) const  
*Return pointer to side of label i (Local labelling).*
- int **Contains** (const **Node** \*nd) const  
*Say if element contains given node.*
- int **Contains** (const **Node** &nd) const  
*Say if element contains given node.*
- int **Contains** (const **Side** \*sd) const  
*Say if element contains given side.*
- int **Contains** (const **Side** &sd) const  
*Say if element contains given side.*
- **Element** \* **getNeighborElement** (size\_t i) const

- Return pointer to element Neighboring element.*

  - `size_t getNbNeigElements () const`  
*Return number of neighboring elements.*
  - `real_t getMeasure () const`  
*Return measure of element.*
  - `Point< real_t > getUnitNormal (size_t i) const`  
*Return outward unit normal to i-th side of element.*
  - `bool isOnBoundary () const`  
*Say if current element is a boundary element or not.*
  - `Node * operator() (size_t i)`  
*Operator ().*
  - `int setSide (size_t n, size_t *nd)`  
*Initialize information on element sides.*
  - `bool isActive () const`  
*Return true or false whether element is active or not.*
  - `int getLevel () const`  
*Return element level Element level decreases when element is refined (starting from 0). If the level is 0, then the element has no father.*
  - `void setChild (Element *el)`  
*Assign element as child of current one and assign current element as father This function is principally used when refining is invoked (e.g. for mesh adaption)*
  - `Element * getChild (size_t i) const`  
*Return pointer to i-th child element Return null pointer is no childs.*
  - `size_t getNbChilds () const`  
*Return number of children of element.*
  - `Element * getParent () const`  
*Return pointer to parent element Return null if no parent.*
  - `size_t IsIn (const Node *nd)`  
*Check if a given node belongs to current element.*

### 7.24.1 Detailed Description

To store and treat finite element geometric information.

Class `Element` enables defining an element of a finite element mesh. The element is given in particular by its shape and a list of nodes. Each node can be accessed by the member function `getPtrNode`. Moreover, class `Mesh` can generate for each element its list of sides. The string that defines the element shape must be chosen according to the following list :

#### Remarks

Once a `Mesh` instance is constructed, one has access for each `Element` of the mesh to pointers to element sides provided the member function `getAllSides` of `Mesh` has been invoked. With this, an element can be tested to see if it is on the boundary, i.e. if it has at least one side on the boundary

### 7.24.2 Constructor & Destructor Documentation

`Element ( size_t label, const string & shape )`

Constructor initializing label, shape of element.

Parameters

|                 |              |                                           |
|-----------------|--------------|-------------------------------------------|
| <code>in</code> | <i>label</i> | Label to assign to element.               |
| <code>in</code> | <i>shape</i> | Shape of element (See class description). |

**Element ( `size_t label`, `int shape` )**

Constructor initializing label, shape of element.

Parameters

|                 |              |                                                                                |
|-----------------|--------------|--------------------------------------------------------------------------------|
| <code>in</code> | <i>label</i> | Label to assign to element.                                                    |
| <code>in</code> | <i>shape</i> | Shape of element (See enum <code>ElementShape</code> in <a href="#">Mesh</a> ) |

**Element ( `size_t label`, `const string & shape`, `int c` )**

Constructor initializing label, shape and code of element.

Parameters

|                 |              |                                                          |
|-----------------|--------------|----------------------------------------------------------|
| <code>in</code> | <i>label</i> | Label to assign to element.                              |
| <code>in</code> | <i>shape</i> | Shape of element (See class description).                |
| <code>in</code> | <i>c</i>     | Code to assign to element (useful for media properties). |

**Element ( `size_t label`, `int shape`, `int c` )**

Constructor initializing label, shape and code of element.

Parameters

|                 |              |                                                                                 |
|-----------------|--------------|---------------------------------------------------------------------------------|
| <code>in</code> | <i>label</i> | Label to assign to element.                                                     |
| <code>in</code> | <i>shape</i> | Shape of element (See enum <code>ElementShape</code> in <a href="#">Mesh</a> ). |
| <code>in</code> | <i>c</i>     | Code to assign to element (useful for media properties).                        |

### 7.24.3 Member Function Documentation

**void setLabel ( `size_t i` )**

Define label of element.

Parameters

|                 |          |                            |
|-----------------|----------|----------------------------|
| <code>in</code> | <i>i</i> | Label to assign to element |
|-----------------|----------|----------------------------|

**void setCode ( `int c` )**

Define code of element.

Parameters

|                 |          |                            |
|-----------------|----------|----------------------------|
| <code>in</code> | <i>c</i> | Code to assign to element. |
|-----------------|----------|----------------------------|

**void setCode ( `const string & exp`, `int code` )**

Define code by a boolean algebraic expression invoking coordinates of element nodes.

Parameters

|    |             |                                                                  |
|----|-------------|------------------------------------------------------------------|
| in | <i>exp</i>  | Boolean algebraic expression as required by <code>fparser</code> |
| in | <i>code</i> | Code to assign to node if the algebraic expression is true       |

**void Add ( Node \* node )**

Insert a node at end of list of nodes of element.

Parameters

|    |             |                                           |
|----|-------------|-------------------------------------------|
| in | <i>node</i> | Pointer to <a href="#">Node</a> instance. |
|----|-------------|-------------------------------------------|

**void Add ( Node \* node, int n )**

Insert a node and set its local node number.

Parameters

|    |             |                                               |
|----|-------------|-----------------------------------------------|
|    | <i>node</i> | [in] Pointer to <a href="#">Node</a> instance |
| in | <i>n</i>    | <a href="#">Element</a> node number to assign |

**void Replace ( size\_t label, Node \* node )**

Replace a node at a given local label.

Parameters

|    |              |                                                                       |
|----|--------------|-----------------------------------------------------------------------|
| in | <i>label</i> | <a href="#">Node</a> to replace.                                      |
| in | <i>node</i>  | Pointer to <a href="#">Node</a> instance to copy to current instance. |

**void Replace ( size\_t label, Side \* side )**

Replace a side at a given local label.

Parameters

|    |              |                                                                       |
|----|--------------|-----------------------------------------------------------------------|
| in | <i>label</i> | <a href="#">Side</a> to replace.                                      |
| in | <i>side</i>  | Pointer to <a href="#">Side</a> instance to copy to current instance. |

**void Add ( Side \* sd )**

Assign [Side](#) to [Element](#).

Parameters

|    |           |                                           |
|----|-----------|-------------------------------------------|
| in | <i>sd</i> | Pointer to <a href="#">Side</a> instance. |
|----|-----------|-------------------------------------------|

**void Add ( Side \* sd, int k )**

Assign [Side](#) to [Element](#) with assigned local label.

Parameters

|    |           |                                           |
|----|-----------|-------------------------------------------|
| in | <i>sd</i> | Pointer to <a href="#">Side</a> instance. |
| in | <i>k</i>  | Local label.                              |

**void Add ( Element \* *el* )**

Add a neighbor element.



Parameters

|                 |                 |                                             |
|-----------------|-----------------|---------------------------------------------|
| <code>in</code> | <code>el</code> | Pointer to <a href="#">Element</a> instance |
|-----------------|-----------------|---------------------------------------------|

**void set ( Element \* *el*, int *n* )**

Add a neighbor element and set its label.

Parameters

|                 |                 |                                             |
|-----------------|-----------------|---------------------------------------------|
| <code>in</code> | <code>el</code> | Pointer to <a href="#">Element</a> instance |
| <code>in</code> | <code>n</code>  | Neighbor element number to assign           |

**void setDOF ( size\_t *i*, size\_t *dof* )**

Define label of DOF.

Parameters

|                 |                  |                         |
|-----------------|------------------|-------------------------|
| <code>in</code> | <code>i</code>   | Index of DOF.           |
| <code>in</code> | <code>dof</code> | Label of DOF to assign. |

**void setCode ( size\_t *dof*, int *code* )**

Assign code to a DOF.

Parameters

|                 |                   |                              |
|-----------------|-------------------|------------------------------|
| <code>in</code> | <code>dof</code>  | Index of dof for assignment. |
| <code>in</code> | <code>code</code> | Code to assign.              |

**Node\* operator() ( size\_t *i* ) const**

Operator ().

Return pointer to node of local label *i*.

**int Contains ( const Node \* *nd* ) const**

Say if element contains given node.

This function tests if the element contains a node with the same pointer at the sought one

Parameters

|                 |                 |                                          |
|-----------------|-----------------|------------------------------------------|
| <code>in</code> | <code>nd</code> | Pointer to <a href="#">Node</a> instance |
|-----------------|-----------------|------------------------------------------|

Returns

Local node label in element. If 0, the element does not contain this node

**int Contains ( const Node & *nd* ) const**

Say if element contains given node.

This function tests if the element contains a node with the same label at the sought one

## Parameters

|           |           |                                            |
|-----------|-----------|--------------------------------------------|
| <b>in</b> | <i>nd</i> | Reference to <a href="#">Node</a> instance |
|-----------|-----------|--------------------------------------------|

## Returns

Local node label in element. If 0, the element does not contain this node

**int Contains ( const Side \* *sd* ) const**

Say if element contains given side.

This function tests if the element contains a side with the same pointer at the sought one

## Parameters

|           |           |                                          |
|-----------|-----------|------------------------------------------|
| <b>in</b> | <i>sd</i> | Pointer to <a href="#">Side</a> instance |
|-----------|-----------|------------------------------------------|

## Returns

Local side label in element. If 0, the element does not contain this side

**int Contains ( const Side & *sd* ) const**

Say if element contains given side.

This function tests if the element contains a side with the same label at the sought one

## Parameters

|           |           |                                            |
|-----------|-----------|--------------------------------------------|
| <b>in</b> | <i>sd</i> | Reference to <a href="#">Side</a> instance |
|-----------|-----------|--------------------------------------------|

## Returns

Local side label in element. If 0, the element does not contain this side

**Element\* getNeighborElement ( size\_t *i* ) const**

Return pointer to element Neighboring element.

## Parameters

|           |          |                               |
|-----------|----------|-------------------------------|
| <b>in</b> | <i>i</i> | Index of element to look for. |
|-----------|----------|-------------------------------|

## Note

This method returns valid information only if the [Mesh](#) member function [Mesh::getElementNeighborElements\(\)](#) has been called before.

**size\_t getNbNeigElements ( ) const**

Return number of neighboring elements.

## Note

This method returns valid information only if the [Mesh](#) member function [Mesh::getElementNeighborElements\(\)](#) has been called before.

**real\_t getMeasure ( ) const**

Return measure of element.

This member function returns length, area or volume of element. In case of quadrilaterals and hexahedrals it returns determinant of Jacobian of mapping between reference and actual element

**Point<real\_t> getUnitNormal ( size\_t i ) const**

Return outward unit normal to i-th side of element.

Sides are ordered [node\_1,node\_2], [node\_2,node\_3], ...

**bool isOnBoundary ( ) const**

Say if current element is a boundary element or not.

Note

this information is available only if boundary elements were determined i.e. if member function [Mesh::getBoundarySides](#) or [Mesh::getAllSides](#) has been invoked before.

**Node\* operator() ( size\_t i )**

Operator ().

Return pointer to node of local label i.

**int setSide ( size\_t n, size\_t \* nd )**

Initialize information on element sides.

This function is to be used to initialize loops over sides.

Parameters

|    |           |                                                                                             |
|----|-----------|---------------------------------------------------------------------------------------------|
| in | <i>n</i>  | Label of side.                                                                              |
| in | <i>nd</i> | Array of pointers to nodes of the side (nd[0], nd[1], ... point to first, second nodes, ... |

**void setChild ( Element \* el )**

Assign element as child of current one and assign current element as father This function is principally used when refining is invoked (e.g. for mesh adaption)

Parameters

|    |           |                              |
|----|-----------|------------------------------|
| in | <i>el</i> | Pointer to element to assign |
|----|-----------|------------------------------|

**size\_t IsIn ( const Node \* nd )**

Check if a given node belongs to current element.

Parameters

|    |           |                           |
|----|-----------|---------------------------|
| in | <i>nd</i> | Pointer to node to locate |
|----|-----------|---------------------------|

Returns

local label of node if this one is found, 0 otherwise

## 7.25 ElementList Class Reference

Class to construct a list of elements having some common properties.

### Public Member Functions

- [ElementList](#) ([Mesh](#) &ms)  
*Constructor using a [Mesh](#) instance.*
- [~ElementList](#) ()  
*Destructor.*
- void [selectCode](#) (int code)  
*Select elements having a given code.*
- void [unselectCode](#) (int code)  
*Unselect elements having a given code.*
- void [selectLevel](#) (int level)  
*Select elements having a given level.*
- size\_t [getNbElements](#) () const  
*Return number of selected elements.*
- void [top](#) ()  
*Reset list of elements at its top position (Non constant version)*
- void [top](#) () const  
*Reset list of elements at its top position (Constant version)*
- [Element](#) \* [get](#) ()  
*Return pointer to current element and move to next one (Non constant version)*
- [Element](#) \* [get](#) () const  
*Return pointer to current element and move to next one (Constant version)*

### 7.25.1 Detailed Description

Class to construct a list of elements having some common properties.

This class enables choosing multiple selection criteria by using function `select...` However, the intersection of these properties must be empty.

### 7.25.2 Member Function Documentation

**void unselectCode ( int code )**

Unselect elements having a given code.

Parameters

|           |             |                             |
|-----------|-------------|-----------------------------|
| <b>in</b> | <i>code</i> | Code of elements to exclude |
|-----------|-------------|-----------------------------|

**void selectLevel ( int level )**

Select elements having a given level.

Parameters

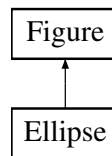
|           |              |                             |
|-----------|--------------|-----------------------------|
| <b>in</b> | <i>level</i> | Level of elements to select |
|-----------|--------------|-----------------------------|

Elements having a given level (for mesh adaption) are selected in a list

## 7.26 Ellipse Class Reference

To store and treat an ellipsoidal figure.

Inheritance diagram for Ellipse:



### Public Member Functions

- `Ellipse ()`  
*Default constructor.*
- `Ellipse (Point< real.t > c, real.t a, real.t b, int code=1)`  
*Constructor with given data.*
- `real.t getSignedDistance (const Point< real.t > &p) const`  
*Return signed distance of a given point from the current ellipse.*
- `Ellipse & operator+= (Point< real.t > a)`  
*Operator +=*
- `Ellipse & operator*= (real.t a)`  
*Operator \*=*
- `void setCode (int code)`  
*Choose a code for the domain defined by the figure.*
- `void getSignedDistance (const Grid &g, Vect< real.t > &d) const`  
*Calculate signed distance to current figure with respect to grid points.*
- `real.t dLine (const Point< real.t > &p, const Point< real.t > &a, const Point< real.t > &b) const`  
*Compute signed distance from a line.*

### 7.26.1 Detailed Description

To store and treat an ellipsoidal figure.

### 7.26.2 Constructor & Destructor Documentation

#### `Ellipse ( )`

Default constructor.

Constructs an ellipse with semimajor axis = 1, and semiminor axis = 1

#### `Ellipse ( Point< real.t > c, real.t a, real.t b, int code = 1 )`

Constructor with given data.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>c</i>    | Coordinates of center                               |
| in | <i>a</i>    | Semimajor axis                                      |
| in | <i>b</i>    | Semiminor axis                                      |
| in | <i>code</i> | Code to assign to the generated figure [Default: 1] |

### 7.26.3 Member Function Documentation

**real\_t getSignedDistance ( const Point< real\_t > & p ) const** [virtual]

Return signed distance of a given point from the current ellipse.

The computed distance is negative if p lies in the ellipse, positive if it is outside, and 0 on its boundary

Parameters

|    |          |                        |
|----|----------|------------------------|
| in | <i>p</i> | Point<double> instance |
|----|----------|------------------------|

Reimplemented from [Figure](#).

**Ellipse& operator+= ( Point< real\_t > a )**

Operator +=

Translate ellipse by a vector a

**Ellipse& operator+= ( real\_t a )**

Operator \*=

Scale ellipse by a factor a

**void getSignedDistance ( const Grid & g, Vect< real\_t > & d ) const** [inherited]

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |          |                                                                                                             |
|----|----------|-------------------------------------------------------------------------------------------------------------|
| in | <i>g</i> | <a href="#">Grid</a> instance                                                                               |
| in | <i>d</i> | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector d doesn't need to be sized before invoking this function

**real\_t dLine ( const Point< real\_t > & p, const Point< real\_t > & a, const Point< real\_t > & b ) const** [inherited]

Compute signed distance from a line.

Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> for which distance is computed |
| in | <i>a</i> | First vertex of line                                 |
| in | <i>b</i> | Second vertex of line                                |

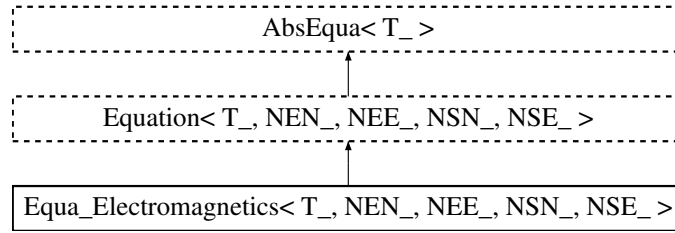
Returns

Signed distance

## 7.27 Equa\_Electromagnetics< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for Electromagnetics [Equation](#) classes.

Inheritance diagram for Equa\_Electromagnetics< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >:



## Public Member Functions

- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)

- Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)
- Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const
- Return number of element nodes.*
- size\_t [getNbEq](#) () const
- Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const
- Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()



*Return reference to linear solver instance.*

- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)

*Choose solver for the linear system.*

- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)

*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > [eMat](#)

*LocalMatrix instance containing local matrix associated to current element.*

- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > [sMat](#)

*LocalMatrix instance containing local matrix associated to current side.*

- [LocalVect](#)< T\_, NEE\_ > [ePrev](#)

*LocalVect instance containing local vector associated to current element.*

- [LocalVect](#)< T\_, NEE\_ > [eRHS](#)

*LocalVect instance containing local right-hand side vector associated to current element.*

- [LocalVect](#)< T\_, NEE\_ > [eRes](#)

*LocalVect instance containing local residual vector associated to current element.*

- [LocalVect](#)< T\_, NSE\_ > [sRHS](#)

*LocalVect instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void [MagneticPermeability](#) (const [real\\_t](#) &mu)

*Set (constant) magnetic permeability.*

- void [MagneticPermeability](#) (const string &exp)

*Set magnetic permeability given by an algebraic expression.*

- void [ElectricConductivity](#) (const [real\\_t](#) &sigma)

*Set (constant) electric conductivity.*

- void [ElectricConductivity](#) (const string &exp)

*set electric conductivity given by an algebraic expression*

- void [ElectricResistivity](#) (const [real\\_t](#) &rho)

*Set (constant) electric resistivity.*

- void [ElectricResistivity](#) (const string &exp)

*Set electric resistivity given by an algebraic expression.*

- void [setMaterial](#) ()

*Set material properties.*

- void [Init](#) (const [Element](#) \*el)

*Set element arrays to zero.*

- void [Init](#) (const [Side](#) \*sd)

*Set side arrays to zero.*

### 7.27.1 Detailed Description

`template<class T_, size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa-  
Electromagnetics< T_, NEN_, NEE_, NSN_, NSE_ >`

Abstract class for Electromagnetics [Equation](#) classes.

### Template Parameters

|        |                                |
|--------|--------------------------------|
| <T_>   | data type (double, float, ...) |
| <NEN>  | Number of element nodes        |
| <NEE_> | Number of element equations    |
| <NSN_> | Number of side nodes           |
| <NSE_> | Number of side equations       |

## 7.27.2 Member Function Documentation

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                          |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute ePrev. This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T<sub>-</sub> > & *b*, LocalVect< T<sub>-</sub>, NEE<sub>-</sub> > & *be* )**  
 [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T<sub>-</sub> > & *b*, LocalVect< T<sub>-</sub>, NEN<sub>-</sub> > & *be*, int *dof* )**  
 [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T<sub>-</sub> > & *b*, LocalVect< T<sub>-</sub>, NEN<sub>-</sub> > & *be* )**  
 [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T<sub>-</sub> > & *b*, LocalVect< T<sub>-</sub>, NSE<sub>-</sub> > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.  
Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.  
Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer *\_theSide*

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array *\_x[0]*, *\_x[1]*, ... which are instances of class [Point<real.t>](#)

Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]` , `_x[1]` , ... which are instances of class [Point<real\\_t>](#)

Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                               |
|---|---------------------------------------------------------------|
| A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|---|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
 [inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | pc | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul> |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |   |                                                                                 |
|--------|---|---------------------------------------------------------------------------------|
| in     | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | b | Vector containing right-hand side                                               |
| in,out | x | Vector containing initial guess of solution on input, actual solution on output |

### 7.27.3 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

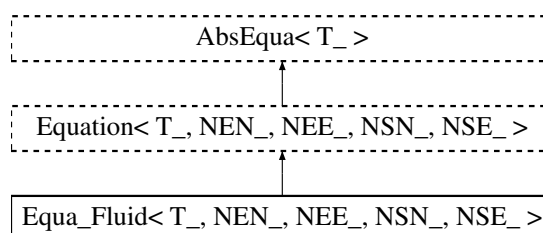
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.28 Equa\_Fluid< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for Fluid Dynamics [Equation](#) classes.

Inheritance diagram for Equa\_Fluid< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >:



### Public Member Functions

- [Equa\\_Fluid](#) ()  
*Default constructor.*
- virtual [~Equa\\_Fluid](#) ()  
*Destructor.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*

- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (**PETScVect**< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (**Matrix**< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*

- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T\_, NEE\_, NEE\_ > **eMat**  
*LocalMatrix* instance containing local matrix associated to current element.
- **LocalMatrix**< T\_, NSE\_, NSE\_ > **sMat**  
*LocalMatrix* instance containing local matrix associated to current side.
- **LocalVect**< T\_, NEE\_ > **ePrev**  
*LocalVect* instance containing local vector associated to current element.
- **LocalVect**< T\_, NEE\_ > **eRHS**  
*LocalVect* instance containing local right-hand side vector associated to current element.
- **LocalVect**< T\_, NEE\_ > **eRes**  
*LocalVect* instance containing local residual vector associated to current element.
- **LocalVect**< T\_, NSE\_ > **sRHS**  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void **Viscosity** (const **real.t** &visc)  
*Set (constant) Viscosity.*
- void **Viscosity** (const string &exp)  
*Set viscosity given by an algebraic expression.*
- void **Density** (const **real.t** &dens)  
*Set (constant) Viscosity.*
- void **Density** (const string &exp)  
*Set Density given by an algebraic expression.*
- void **ThermalExpansion** (const **real.t** \*e)  
*Set (constant) thermal expansion coefficient.*
- void **ThermalExpansion** (const string &exp)  
*Set thermal expansion coefficient given by an algebraic expression.*
- void **setMaterial** ()  
*Set material properties.*
- void **Init** (const **Element** \*el)  
*Set element arrays to zero.*
- void **Init** (const **Side** \*sd)  
*Set side arrays to zero.*

### 7.28.1 Detailed Description

**template<class T\_, size\_t NEN\_, size\_t NEE\_, size\_t NSN\_, size\_t NSE\_>class OFELI::Equa-  
Fluid< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >**

Abstract class for Fluid Dynamics **Equation** classes.

Template Parameters

|        |                                |
|--------|--------------------------------|
| <T_>   | data type (double, float, ...) |
| <NEN_> | Number of element nodes        |
| <NEE_> | Number of element equations    |
| <NSN_> | Number of side nodes           |
| <NSE_> | Number of side equations       |

## 7.28.2 Constructor & Destructor Documentation

### **Equa\_Fluid ( )**

Default constructor.

Constructs an empty equation.

## 7.28.3 Member Function Documentation

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                          |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute ePrev. This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.



Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer *\_theSide*

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array *\_x[0]*, *\_x[1]*, ... which are instances of class [Point<real.t>](#)

# Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real\\_t>](#)

# Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

# Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

# Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

# Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                               |
|---|---------------------------------------------------------------|
| A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|---|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

## 7.28.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

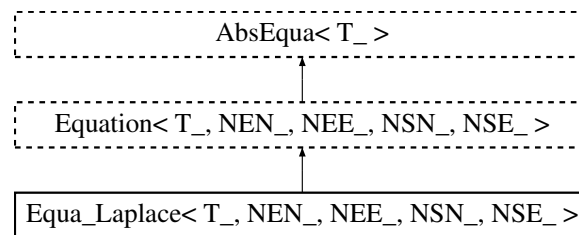
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.29 Equa\_Laplace< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for classes about the Laplace equation.

Inheritance diagram for Equa\_Laplace< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >:



## Public Member Functions

- [Equa\\_Laplace](#) ()  
*Default constructor.*
- virtual [~Equa\\_Laplace](#) ()  
*Destructor.*
- virtual void [build](#) ()  
*Solve the equation.*
- virtual void [buildEigen](#) (int opt=0)  
*Build matrices for an eigenvalue problem.*
- void [build](#) ([EigenProblemSolver](#) &e)  
*Build the linear system for an eigenvalue problem.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [DiagBC](#) (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void [LocalNodeVector](#) ([Vect](#)< T\_ > &b)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEE\_ > &be)



- Localize *Element* Vector from a *Vect* instance.

  - void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)
- Localize *Element* Vector from a *Vect* instance.

  - void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)
- Localize *Element* Vector from a *Vect* instance.

  - void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)
- Localize *Element* Vector from a *Vect* instance.

  - void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)
- Localize *Element* Vector.

  - void **SideVector** (const **Vect**< T\_ > &b)
- Localize *Side* Vector.

  - void **ElementNodeCoordinates** ()
- Localize coordinates of element nodes.

  - void **SideNodeCoordinates** ()
- Localize coordinates of side nodes.

  - void **ElementAssembly** (**Matrix**< T\_ > \*A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**PETScMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**PETScVect**< T\_ > &b)
- Assemble element right-hand side vector into global one.

  - void **ElementAssembly** (**BMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**SkSMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**SkMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**SpMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**TrMatrix**< T\_ > &A)
- Assemble element matrix into global one.

  - void **ElementAssembly** (**Vect**< T\_ > &v)
- Assemble element vector into global one.

  - void **SideAssembly** (**PETScMatrix**< T\_ > &A)
- Assemble side matrix into global one.

  - void **SideAssembly** (**PETScVect**< T\_ > &b)
- Assemble side right-hand side vector into global one.

  - void **SideAssembly** (**Matrix**< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.

  - void **SideAssembly** (**SkSMatrix**< T\_ > &A)
- Assemble side (edge or face) matrix into global one.

  - void **SideAssembly** (**SkMatrix**< T\_ > &A)
- Assemble side (edge or face) matrix into global one.

  - void **SideAssembly** (**SpMatrix**< T\_ > &A)
- Assemble side (edge or face) matrix into global one.

  - void **SideAssembly** (**Vect**< T\_ > &v)

- Assemble side (edge or face) vector into global one.*

## Public Attributes

- `calMatrix` < T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > eMat  
*LocalMatrix* instance containing local matrix associated to current element.

## Protected Member Functions

- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.29.1 Detailed Description

**template<class T\_, size\_t NEN\_, size\_t NEE\_, size\_t NSN\_, size\_t NSE\_>class OFELI::Equa-  
Laplace< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >**

Abstract class for classes about the Laplace equation.

**Template Arguments:**

- **T\_** : data type (double, float, ...)
- **NEN\_** : Number of element nodes
- **NEE\_** : Number of element equations
- **NSN\_** : Number of side nodes
- **NSE\_** : Number of side equations

### 7.29.2 Constructor & Destructor Documentation

**EquaLaplace ( )**

Default constructor.

Constructs an empty equation.

### 7.29.3 Member Function Documentation

**void build ( EigenProblemSolver & e )**

Build the linear system for an eigenvalue problem.

Parameters

|           |          |                                                               |
|-----------|----------|---------------------------------------------------------------|
| <b>in</b> | <i>e</i> | Reference to used <a href="#">EigenProblemSolver</a> instance |
|-----------|----------|---------------------------------------------------------------|

**void updateBC ( const Element & el, const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>el</i> | Reference to current element instance           |
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |    |                                                 |
|----|----|-------------------------------------------------|
| in | bc | Vector that contains imposed values at all DOFs |
|----|----|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |          |                                                                                                                                                                                                                                                                           |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | dof_type | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | dof      | DOF setting: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF No. dof is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |   |                                                                                                                                                                                                                        |
|----|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | b | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|---|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |    |                                                                             |
|-----|----|-----------------------------------------------------------------------------|
| in  | b  | Global vector to be localized.                                              |
| out | be | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the degree of freedom is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                             |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number dof is handled in the system</li> </ul> The resulting local vector can be accessed by attribute ePrev.                            |



Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|      |     |                                                              |
|------|-----|--------------------------------------------------------------|
| $in$ | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|   |                            |
|---|----------------------------|
| A | Reference to global matrix |
|---|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|   |                                            |
|---|--------------------------------------------|
| b | Reference to global right-hand side vector |
|---|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.



Parameters

|  |          |                                                                                                                                                  |
|--|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|
|  | <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|----------|--------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | Global vector ( <a href="#">Vect</a> instance) |
|----|----------|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|          |                                                               |
|----------|---------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|         |          |                                                                                 |
|---------|----------|---------------------------------------------------------------------------------|
| in      | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in      | <i>b</i> | Vector containing right-hand side                                               |
| in, out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

## 7.29.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

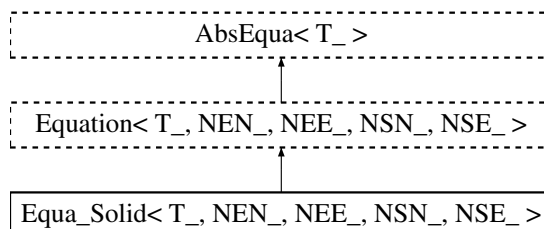
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.30 `Equa_Solid< T_, NEN_, NEE_, NSN_, NSE_ >` Class Template Reference

Abstract class for Solid Mechanics Finite Element classes.

Inheritance diagram for `Equa_Solid< T_, NEN_, NEE_, NSN_, NSE_ >`:



### Public Member Functions

- `Equa_Solid ()`  
*Default constructor.*
- virtual `~Equa_Solid ()`  
*Destructor.*
- virtual void `LMassToLHS (real.t coef=1)`  
*Add lumped mass contribution to left-hand side.*
- virtual void `LMassToRHS (real.t coef=1)`  
*Add lumped mass contribution to right-hand side.*
- virtual void `MassToLHS (real.t coef=1)`  
*Add consistent mass contribution to left-hand side.*
- virtual void `MassToRHS (real.t coef=1)`  
*Add consistent mass contribution to right-hand side.*
- void `setLumpedMass ()`  
*Add lumped mass contribution to left and right-hand sides taking into account time integration scheme.*
- void `setMass ()`  
*Add consistent mass contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void `Mass (real.t coef=1)`  
*Add consistent mass matrix to left-hand side after multiplication by coef [Default: 1].*
- virtual void `LMass (real.t coef=1)`  
*Add lumped mass matrix to left-hand side after multiplication by coef [Default: 1].*
- virtual void `Deviator (real.t coef=1)`  
*Add deviator matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void `Dilatation (real.t coef=1)`  
*Add dilatation matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void `DilatationToRHS (real.t coef=1)`  
*Add dilatation vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void `DeviatorToRHS (real.t coef=1)`  
*Add deviator vector to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*

- virtual void **Stiffness** (real\_t coef=1)  
*Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- virtual void **StiffnessToRHS** (real\_t coef=1)  
*Add stiffness matrix to right-hand side taking into account time integration scheme, after multiplication by coef [Default: 1].*
- void **setDilatation** ()  
*Add dilatation matrix to left and/or right-hand side taking into account time.*
- void **setDeviator** ()  
*Add deviator matrix to left and/or right-hand side taking into account time integration scheme.*
- void **setStiffness** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)

- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble element vector into global one.*

  - void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)
- Assemble side matrix into global one.*

  - void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble side right-hand side vector into global one.*

  - void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*

  - void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*

  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*

  - size\_t [getNbNodes](#) () const
- Return number of element nodes.*

  - size\_t [getNbEq](#) () const
- Return number of element equations.*

  - void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*

  - [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*

  - void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*

  - [Mesh](#) & [getMesh](#) () const

- *Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > [eMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > [sMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > [ePrev](#)  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > [eRHS](#)  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > [eRes](#)  
*[LocalVect](#) instance containing local residual vector associated to current element.*
- [LocalVect](#)< T\_, NSE\_ > [sRHS](#)  
*[LocalVect](#) instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void [Young](#) (const [real\\_t](#) &E)  
*Set (constant) Young modulus.*
- void [Poisson](#) (const [real\\_t](#) &nu)  
*Set (constant) Poisson ratio.*
- void [Density](#) (const [real\\_t](#) &rho)  
*Set (constant) density.*
- void [Young](#) (const string &exp)  
*Set Young modulus given by an algebraic expression.*
- void [Poisson](#) (const string &exp)  
*Set Poisson ratio given by an algebraic expression.*
- void [Density](#) (const string &exp)  
*Set density given by an algebraic expression.*
- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.30.1 Detailed Description

`template<class T_, size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa-  
Solid< T_, NEN_, NEE_, NSN_, NSE_ >`

Abstract class for Solid Mechanics Finite Element classes.



## Template Parameters

|                           |                                |
|---------------------------|--------------------------------|
| <code>&lt;T_&gt;</code>   | data type (double, float, ...) |
| <code>&lt;NEN&gt;</code>  | Number of element nodes        |
| <code>&lt;NEE_&gt;</code> | Number of element equations    |
| <code>&lt;NSN_&gt;</code> | Number of side nodes           |
| <code>&lt;NSE_&gt;</code> | Number of side equations       |

### 7.30.2 Constructor & Destructor Documentation

#### **Equa.Solid ( )**

Default constructor.

Constructs an empty equation.

### 7.30.3 Member Function Documentation

#### **virtual void LMassToLHS ( real\_t coef = 1 ) [virtual]**

Add lumped mass contribution to left-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the matrix before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

Reimplemented in [Elas2DT3](#), [Elas2DQ4](#), [Beam3DL2](#), [Elas3DH8](#), [Elas3DT4](#), and [Bar2DL2](#).

#### **virtual void LMassToRHS ( real\_t coef = 1 ) [virtual]**

Add lumped mass contribution to right-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

Reimplemented in [Elas2DT3](#), [Elas2DQ4](#), [Beam3DL2](#), [Elas3DH8](#), [Elas3DT4](#), and [Bar2DL2](#).

#### **virtual void MassToLHS ( real\_t coef = 1 ) [virtual]**

Add consistent mass contribution to left-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the matrix before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

Reimplemented in [Elas2DT3](#), [Beam3DL2](#), and [Bar2DL2](#).

#### **virtual void MassToRHS ( real\_t coef = 1 ) [virtual]**

Add consistent mass contribution to right-hand side.

Parameters

|                 |                   |                                                                  |
|-----------------|-------------------|------------------------------------------------------------------|
| <code>in</code> | <code>coef</code> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------------|-------------------|------------------------------------------------------------------|

Reimplemented in [Elas2DT3](#), [Beam3DL2](#), and [Bar2DL2](#).

#### **void updateBC ( const Element & el, const Vect< T\_ > & bc ) [inherited]**

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF No. dof is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

#### Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

#### Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

#### Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                             |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number dof is handled in the system</li> </ul> The resulting local vector can be accessed by attribute ePrev.                            |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                  |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [ default ]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute ePrev. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

#### Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|  |          |                                                               |
|--|----------|---------------------------------------------------------------|
|  | <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|--|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | Global vector ( <a href="#">Vect</a> instance) |
|----|----------|------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > &  $b$  )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \*  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                  |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|--------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                               |
|---|---------------------------------------------------------------|
| A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|---|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |    |                                                               |
|-----|----|---------------------------------------------------------------|
| in  | el | Reference to <a href="#">Element</a> instance                 |
| in  | x  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | b  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |    |                                                               |
|-----|----|---------------------------------------------------------------|
| in  | sd | Reference to <a href="#">Side</a> instance                    |
| in  | x  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | b  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |      |                      |
|----|------|----------------------|
| in | exp  | Algebraic expression |
| in | prop | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |     |                                                                                 |
|--------|-----|---------------------------------------------------------------------------------|
| in     | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | $b$ | Vector containing right-hand side                                               |
| in,out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

### 7.30.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

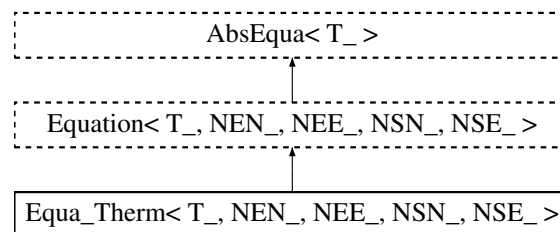
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.31 Equa\_Therm< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for Heat transfer Finite Element classes.

Inheritance diagram for `Equa_Therm< T_, NEN_, NEE_, NSN_, NSE_ >`:



### Public Member Functions

- [Equa\\_Therm](#) ()  
*Default constructor.*
- virtual [~Equa\\_Therm](#) ()  
*Destructor.*
- virtual void [setStab](#) ()  
*Set stabilized formulation.*
- virtual void [LCapacityToLHS](#) ([real.t](#) coef=1)  
*Add lumped capacity contribution to left-hand side.*
- virtual void [LCapacityToRHS](#) ([real.t](#) coef=1)  
*Add lumped capacity contribution to right-hand side.*
- virtual void [CapacityToLHS](#) ([real.t](#) coef=1)  
*Add consistent capacity contribution to left-hand side.*
- virtual void [CapacityToRHS](#) ([real.t](#) coef=1)  
*Add consistent capacity contribution to right-hand side.*

- void **setLumpedCapacity** ()  
*Add lumped capacity contribution to left and right-hand sides taking into account time integration scheme.*
- void **setCapacity** ()  
*Add consistent capacity contribution to left and right-hand sides taking into account time integration scheme.*
- virtual void **Diffusion** (real\_t coef=1.)  
*Add diffusion term to left-hand side.*
- virtual void **DiffusionToRHS** (real\_t coef=1.)  
*Add diffusion term to right-hand side.*
- void **setDiffusion** ()  
*Add diffusion contribution to left and/or right-hand side taking into account time integration scheme.*
- virtual void **Convection** (real\_t coef=1.)  
*Add convection term to left-hand side.*
- virtual void **ConvectionToRHS** (real\_t coef=1.)  
*Add convection term to right-hand side.*
- void **setConvection** ()  
*Add convection contribution to left and/or right-hand side taking into account time integration scheme.*
- virtual void **BodyRHS** (const Vect< real\_t > &bf, int opt=GLOBAL\_ARRAY)  
*Add body right-hand side term to right-hand side.*
- virtual void **BoundaryRHS** (const Vect< real\_t > &sf, int opt=GLOBAL\_ARRAY)  
*Add boundary right-hand side term to right-hand side.*
- void **build** ()  
*Build the linear system of equations.*
- void **build** (TimeStepping &s)  
*Build the linear system of equations.*
- void **build** (EigenProblemSolver &e)  
*Build the linear system for an eigenvalue problem.*
- int **runTransient** ()  
*Run one time step.*
- int **runOneTimeStep** ()  
*Run one time step.*
- int **run** ()  
*Run the equation.*
- void **setRhoCp** (const real\_t &rhocp)  
*Set product of Density by Specific heat (constants)*
- void **setConductivity** (const real\_t &diff)  
*Set (constant) thermal conductivity.*
- void **RhoCp** (const string &exp)  
*Set product of Density by Specific heat given by an algebraic expression.*
- void **Conduc** (const string &exp)  
*Set thermal conductivity given by an algebraic expression.*
- void **updateBC** (const Element &el, const Vect< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const Vect< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE\_DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*

- void `LocalNodeVector` (`Vect`< `T_` > &`b`)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEE_` > &`be`)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEN_` > &`be`, int dof)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEN_` > &`be`)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NSE_` > &`be`)  
*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< `T_` > &`b`, int dof\_type=NODE.FIELD, int flag=0)  
*Localize `Element` Vector.*
- void `SideVector` (const `Vect`< `T_` > &`b`)  
*Localize `Side` Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()  
*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix`< `T_` > \*`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScVect`< `T_` > &`b`)  
*Assemble element right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SpMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`TrMatrix`< `T_` > &`A`)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`Vect`< `T_` > &`v`)  
*Assemble element vector into global one.*
- void `SideAssembly` (`PETScMatrix`< `T_` > &`A`)  
*Assemble side matrix into global one.*
- void `SideAssembly` (`PETScVect`< `T_` > &`b`)  
*Assemble side right-hand side vector into global one.*
- void `SideAssembly` (`Matrix`< `T_` > \*`A`)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkSMatrix`< `T_` > &`A`)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkMatrix`< `T_` > &`A`)  
*Assemble side (edge or face) matrix into global one.*

- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > eMat  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > sMat  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > ePrev  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*

- [LocalVect](#)<  $T\_$ ,  $\text{NEE\_}$  > [eRes](#)  
*LocalVect instance containing local residual vector associated to current element.*
- [LocalVect](#)<  $T\_$ ,  $\text{NSE\_}$  > [sRHS](#)  
*LocalVect instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.31.1 Detailed Description

**template<class  $T\_$ , size\_t  $\text{NEN\_}$ , size\_t  $\text{NEE\_}$ , size\_t  $\text{NSN\_}$ , size\_t  $\text{NSE\_}$ >class OFELI::Equa-  
Therm<  $T\_$ ,  $\text{NEN\_}$ ,  $\text{NEE\_}$ ,  $\text{NSN\_}$ ,  $\text{NSE\_}$  >**

Abstract class for Heat transfer Finite Element classes.  
Template Parameters

|                    |                                |
|--------------------|--------------------------------|
| < $T\_$ >          | data type (real_t, float, ...) |
| < $\text{NEN\_}$ > | Number of element nodes        |
| < $\text{NEE\_}$ > | Number of element equations    |
| < $\text{NSN\_}$ > | Number of side nodes           |
| < $\text{NSE\_}$ > | Number of side equations       |

### 7.31.2 Constructor & Destructor Documentation

**Equa\_Therm ( )**

Default constructor.  
Constructs an empty equation.

### 7.31.3 Member Function Documentation

**virtual void setStab ( )** [virtual]

Set stabilized formulation.  
Stabilized variational formulations are to be used when the Pclet number is large.  
By default, no stabilization is used.

**virtual void LCapacityToLHS ( real\_t  $coef$  = 1 )** [virtual]

Add lumped capacity contribution to left-hand side.  
Parameters

|    |        |                                                                  |
|----|--------|------------------------------------------------------------------|
| in | $coef$ | coefficient to multiply by the matrix before adding [Default: 1] |
|----|--------|------------------------------------------------------------------|

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC3DAT3](#), and [DC1DL2](#).

**virtual void LCapacityToRHS ( real\_t  $coef$  = 1 )** [virtual]

Add lumped capacity contribution to right-hand side.

Parameters

|           |             |                                                                  |
|-----------|-------------|------------------------------------------------------------------|
| <i>in</i> | <i>coef</i> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------|-------------|------------------------------------------------------------------|

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC3DAT3](#), and [DC1DL2](#).

**virtual void CapacityToLHS ( real\_t coef = 1 ) [virtual]**

Add consistent capacity contribution to left-hand side.

Parameters

|           |             |                                                                  |
|-----------|-------------|------------------------------------------------------------------|
| <i>in</i> | <i>coef</i> | coefficient to multiply by the matrix before adding [Default: 1] |
|-----------|-------------|------------------------------------------------------------------|

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC3DAT3](#), and [DC1DL2](#).

**virtual void CapacityToRHS ( real\_t coef = 1 ) [virtual]**

Add consistent capacity contribution to right-hand side.

Parameters

|           |             |                                                                  |
|-----------|-------------|------------------------------------------------------------------|
| <i>in</i> | <i>coef</i> | coefficient to multiply by the vector before adding [Default: 1] |
|-----------|-------------|------------------------------------------------------------------|

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC3DAT3](#), and [DC1DL2](#).

**virtual void BodyRHS ( const Vect< real\_t > &bf, int opt = GLOBAL\_ARRAY ) [virtual]**

Add body right-hand side term to right-hand side.

Parameters

|           |            |                                                                                                                         |
|-----------|------------|-------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>bf</i>  | Vector containing source at element nodes.                                                                              |
| <i>in</i> | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC2DT6](#), [DC1DL2](#), and [DC3DAT3](#).

**virtual void BoundaryRHS ( const Vect< real\_t > &sf, int opt = GLOBAL\_ARRAY ) [virtual]**

Add boundary right-hand side term to right-hand side.

Parameters

|           |            |                                                                                                                         |
|-----------|------------|-------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>sf</i>  | Vector containing source at side nodes.                                                                                 |
| <i>in</i> | <i>opt</i> | Vector is local (LOCAL_ARRAY) with size 3 or global (GLOBAL_ARRAY) with size = Number of nodes [Default: GLOBAL_ARRAY]. |

Reimplemented in [DC2DT3](#), [DC3DT4](#), [DC2DT6](#), [DC1DL2](#), and [DC3DAT3](#).

**void build ( )**

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.



```
void build (TimeStepping & s)
```

Build the linear system of equations.

Before using this function, one must have properly selected appropriate options for:

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

## Parameters

|    |   |                                                         |
|----|---|---------------------------------------------------------|
| in | s | Reference to used <a href="#">TimeStepping</a> instance |
|----|---|---------------------------------------------------------|

```
void build (EigenProblemSolver & e)
```

Build the linear system for an eigenvalue problem.

## Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $e$ | Reference to used <a href="#">EigenProblemSolver</a> instance |
|----|-----|---------------------------------------------------------------|

```
int runTransient ()
```

Run one time step.

This function performs one time step in equation solving. It is to be used only if a *TRANSIENT* analysis is required.

## Returns

Return error from the linear system solver

```
int runOneTimeStep ()
```

Run one time step.

This function performs one time step in equation solving. It is identical to the function `runTransient`.

## Returns

Return error from the linear system solver

```
int run ()
```

Run the equation.

If the analysis (see function `setAnalysis`) is `STEADY_STATE`, then the function solves the stationary equation.

If the analysis is TRANSIENT, then the function performs time stepping until the final time is reached.

```
void updateBC (const Element &el, const Vect< T_ > &bc) [inherited]
```

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF No. dof is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

#### Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

#### Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

#### Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                             |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number dof is handled in the system</li> </ul> The resulting local vector can be accessed by attribute ePrev.                            |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                  |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [ default ]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute ePrev. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

#### Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

#### Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > &  $b$  )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \*  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

### Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

### Warning

The side pointer is given by the global variable `theSide`

```
void SideAssembly (Vect< T_ > &v) [inherited]
```

Assemble side (edge or face) vector into global one.

### Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

### Warning

The side pointer is given by the global variable theSide

**void DGELEMENTAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

### Warning

The element pointer is given by the global variable `theElement`

```
void DGELEMENTAssembly (SkMatrix< T_ > & A) [inherited]
```

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as an <code>SkSMatrix</code> instance |
|-----|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`.

```
void DGELEMENTASSEMBLY (SkMatrix< T_ > & A) [inherited]
```

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

### Warning

The element pointer is given by the global variable `theElement`.

```
void DGElementAssembly (SpMatrix< T_ > & A) [inherited]
```

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |    |                                                               |
|-----|----|---------------------------------------------------------------|
| in  | el | Reference to <a href="#">Element</a> instance                 |
| in  | x  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | b  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |    |                                                               |
|-----|----|---------------------------------------------------------------|
| in  | sd | Reference to <a href="#">Side</a> instance                    |
| in  | x  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | b  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |      |                      |
|----|------|----------------------|
| in | exp  | Algebraic expression |
| in | prop | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh**& **getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

#### 7.31.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

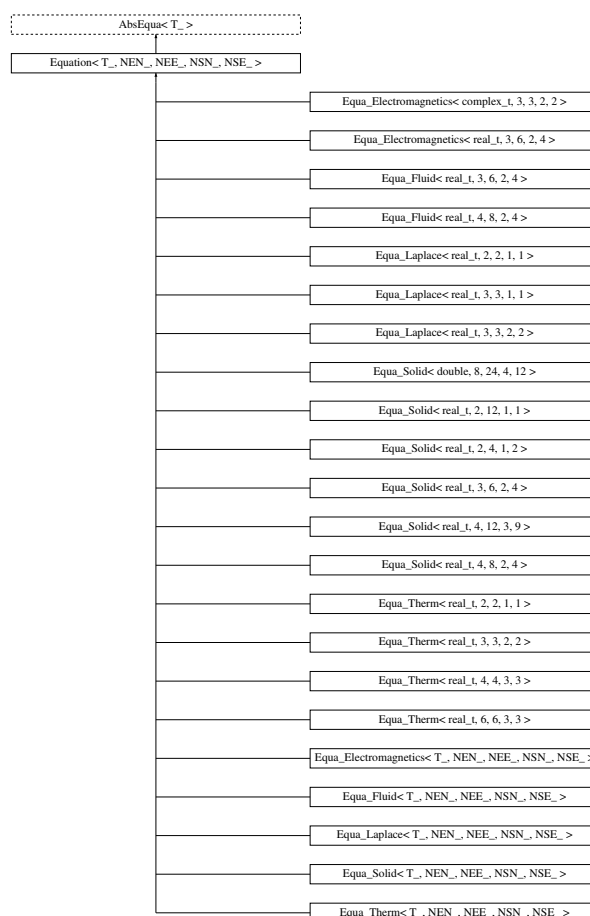
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.32 Equation< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for all equation classes.

Inheritance diagram for Equation< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >:



## Public Member Functions

- [Equation](#) ()  
*Constructor with mesh instance.*
- [Equation](#) ([Mesh](#) &mesh, [Vect](#)< T\_ > &b, [real\\_t](#) &t, [real\\_t](#) &ts)  
*Constructor with mesh instance, matrix and right-hand side.*
- [Equation](#) (const [Element](#) \*el)  
*Constructor using [Element](#) data.*
- [Equation](#) (const [Side](#) \*sd)  
*Constructor using [Side](#) data.*
- [Equation](#) (const [Element](#) \*el, const [Vect](#)< T\_ > &u, [real\\_t](#) time=0)  
*Constructor using element data, solution at previous time step and time value.*
- [Equation](#) (const [Side](#) \*sd, const [Vect](#)< T\_ > &u, [real\\_t](#) time=0)  
*Constructor using side data, solution at previous time step and time value.*
- virtual [~Equation](#) ()  
*Destructor.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< T\_ > &bc)

- Update Right-Hand side by taking into account essential boundary conditions.*

  - void `DiagBC` (int dof\_type=NODE.DOF, int dof=0)
- Update element matrix to impose bc by diagonalization technique.*

  - void `LocalNodeVector` (`Vect`< `T_` > &`b`)

*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEE_` > &`be`)

*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVectorSingleDOF` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEN_` > &`be`)

*Localize `Element` Vector from a `Vect` instance.*
- void `ElementNodeVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NEN_` > &`be`, int dof)

*Localize `Element` Vector from a `Vect` instance.*
- void `ElementSideVector` (const `Vect`< `T_` > &`b`, `LocalVect`< `T_`, `NSE_` > &`be`)

*Localize `Element` Vector from a `Vect` instance.*
- void `ElementVector` (const `Vect`< `T_` > &`b`, int dof\_type=NODE.FIELD, int flag=0)

*Localize `Element` Vector.*
- void `SideVector` (const `Vect`< `T_` > &`b`)

*Localize `Side` Vector.*
- void `ElementNodeCoordinates` ()

*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()

*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix`< `T_` > \*`A`)

*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `SideAssembly` (`PETScMatrix`< `T_` > &`A`)

*Assemble side matrix into global one.*
- void `ElementAssembly` (`PETScVect`< `T_` > &`b`)

*Assemble element right-hand side vector into global one.*
- void `SideAssembly` (`PETScVect`< `T_` > &`b`)

*Assemble side right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `ElementAssembly` (`SpMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `ElementAssembly` (`TrMatrix`< `T_` > &`A`)

*Assemble element matrix into global one.*
- void `DGElementAssembly` (`Matrix`< `T_` > \*`A`)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkSMatrix`< `T_` > &`A`)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkMatrix`< `T_` > &`A`)

- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- *Assemble side (edge or face) matrix into global one.*  
void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- *Assemble side (edge or face) matrix into global one.*  
void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- *Assemble side (edge or face) matrix into global one.*  
void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- *Assemble side (edge or face) matrix into global one.*  
void [ElementAssembly](#) ([Vect](#)< T\_ > &v)
- *Assemble element vector into global one.*  
void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- *Assemble side (edge or face) vector into global one.*  
void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- *Assemble product of element matrix by element vector into global vector.*  
void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- *Assemble product of side matrix by side vector into global vector.*  
size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > [eMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > [sMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > [ePrev](#)

- *`LocalVect` instance containing local vector associated to current element.*  
• `LocalVect< T_, NEE_ > eRHS`  
*`LocalVect` instance containing local right-hand side vector associated to current element.*
- `LocalVect< T_, NEE_ > eRes`  
*`LocalVect` instance containing local residual vector associated to current element.*
- `LocalVect< T_, NSE_ > sRHS`  
*`LocalVect` instance containing local right-hand side vector associated to current side.*

## Protected Member Functions

- void `Init` (const `Element` \*el)  
*Set element arrays to zero.*
- void `Init` (const `Side` \*sd)  
*Set side arrays to zero.*

### 7.32.1 Detailed Description

`template<class T_, size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equation< T_, NEN_, NEE_, NSN_, NSE_ >`

Abstract class for all equation classes.

Template Arguments:

- `T_` : data type (real.t, float, ...)
- `NEN_` : Number of element nodes
- `NEE_` : Number of element equations
- `NSN_` : Number of side nodes
- `NSN_` : Number of side equations

### 7.32.2 Constructor & Destructor Documentation

`Equation ( )`

Default constructor. Constructs an "empty" equation

`Equation ( Mesh & mesh )`

Constructor with mesh instance.

Parameters

|    |             |                            |
|----|-------------|----------------------------|
| in | <i>mesh</i> | <code>Mesh</code> instance |
|----|-------------|----------------------------|

`Equation ( Mesh & mesh, Vect< T_ > & b, real.t & t, real.t & ts )`

Constructor with mesh instance, matrix and right-hand side.

Parameters

|    |             |                                                        |
|----|-------------|--------------------------------------------------------|
| in | <i>mesh</i> | <code>Mesh</code> instance                             |
| in | <i>b</i>    | <code>Vect</code> instance containing Right-hand side. |
| in | <i>t</i>    | Time value                                             |
| in | <i>ts</i>   | Time step                                              |

**Equation ( const Element \* *el* )**

Constructor using [Element](#) data.



Parameters

|    |           |                                    |
|----|-----------|------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a> |
|----|-----------|------------------------------------|

**Equation ( const Element \* *el*, const Vect< T\_ > & *u*, real\_t *time* = 0 )**

Constructor using element data, solution at previous time step and time value.

Parameters

|    |             |                                                                         |
|----|-------------|-------------------------------------------------------------------------|
| in | <i>el</i>   | Pointer to element                                                      |
| in | <i>u</i>    | <a href="#">Vect</a> instance containing solution at previous time step |
| in | <i>time</i> | Time value (Default value is 0)                                         |

**Equation ( const Side \* *sd*, const Vect< T\_ > & *u*, real\_t *time* = 0 )**

Constructor using side data, solution at previous time step and time value.

Parameters

|    |             |                                                                         |
|----|-------------|-------------------------------------------------------------------------|
| in | <i>sd</i>   | Pointer to side                                                         |
| in | <i>u</i>    | <a href="#">Vect</a> instance containing solution at previous time step |
| in | <i>time</i> | Time value (Default value is 0)                                         |

### 7.3.2.3 Member Function Documentation

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )**

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )**

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )**

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )**

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector `b` is assumed to contain only one degree of freedom by node.

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the dega dof is transferred to the local vector

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )**

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                             |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number dof is handled in the system</li> </ul> <p>The resulting local vector can be accessed by attribute ePrev.</p>                     |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer \_theElement

**void SideVector ( const Vect< T\_ > & b )**

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                         |
|----|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [ default ]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> <p>The resulting local vector can be accessed by attribute ePrev.</p> |
|----|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )**

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )**

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )**

Assemble element matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )**

Assemble element matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )**

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void ElementAssembly ( PETScVect< T\_ > & b )**

Assemble element right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScVect< T\_ > & b )**

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void ElementAssembly ( BMatrix< T\_ > & A )**

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )**

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )**

Assemble element matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< T<sub>-</sub> > & A )**

Assemble element matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< T<sub>-</sub> > & A )**

Assemble element matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( Matrix< T<sub>-</sub> > \* A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T<sub>-</sub> > & A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                               |
|---|---------------------------------------------------------------|
| A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|---|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkMatrix< T<sub>-</sub> > & A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( Matrix< T\_ > \* A )**

Assemble side (edge or face) matrix into global one.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )**

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )**

Assemble side (edge or face) matrix into global one.

## 7.32. EQUATION< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > ~~CLASS TEMPLATE~~ ~~DECLARATION~~ ~~IMPLEMENTATION~~

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )**

Assemble side (edge or face) matrix into global one.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void ElementAssembly ( Vect< T\_ > & v )**

Assemble element vector into global one.

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | Global vector ( <a href="#">Vect</a> instance) |
|----|----------|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( Vect< T\_ > & v )**

Assemble side (edge or face) vector into global one.

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | Global vector ( <a href="#">Vect</a> instance) |
|----|----------|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )**

Assemble product of side matrix by side vector into global vector.



Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real.t setMaterialProperty ( const string & *exp*, const string & *prop* )**

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

|                 |                 |                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |
|-----------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>pc</code> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• <code>IDENT.PREC</code>, Identity preconditioner (no preconditioning [default])</li> <li>• <code>DIAG.PREC</code>, Diagonal preconditioner</li> <li>• <code>ILU.PREC</code>, Incomplete LU factorization preconditioner</li> </ul> |
|-----------------|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|                     |                |                                                                                 |
|---------------------|----------------|---------------------------------------------------------------------------------|
| <code>in</code>     | <code>A</code> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| <code>in</code>     | <code>b</code> | Vector containing right-hand side                                               |
| <code>in,out</code> | <code>x</code> | Vector containing initial guess of solution on input, actual solution on output |

### 7.32.4 Member Data Documentation

**LocalVect<T\_,NEE-> ePrev**

[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.33 Estimator Class Reference

To calculate an a posteriori estimator of the solution.

### Public Member Functions

- [Estimator](#) ()  
*Default Constructor.*
- [Estimator](#) ([Mesh](#) &m)  
*Constructor using finite element mesh.*
- [~Estimator](#) ()  
*Destructor.*
- void [setError](#) (const [Vect](#)< [real.t](#) > &u)  
*Calculate error using [Vect](#) solution vector u.*
- [real.t](#) [getAverage](#) () const  
*Return averaged error.*
- [Mesh](#) & [getMesh](#) () const  
*Return a reference to the finite element mesh.*

### Public Attributes

- [Vect](#)< [real.t](#) > [Err](#)  
*Elementwise vector error.*

### 7.33.1 Detailed Description

To calculate an a posteriori estimator of the solution.

This class enables calculating an estimator of a solution in order to evaluate reliability. Estimation uses the so-called Zienkiewicz-Zhu estimator.

## 7.34 FastMarching2D Class Reference

To run a Fast Marching Method on 2-D structured uniform grids.

### Public Member Functions

- [FastMarching2D](#) ()  
*Default constructor.*
- [FastMarching2D](#) (const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &ls)  
*Constructor using grid and level set function.*
- [FastMarching2D](#) (const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &ls, [Vect](#)< [real\\_t](#) > &F)  
*Constructor using grid, level set function and velocity to extend.*
- [~FastMarching2D](#) ()  
*Destructor.*
- void [execute](#) ()  
*Execute Fast Marching Procedure.*
- void [Check](#) ()  
*Check distance function.*

### 7.34.1 Detailed Description

To run a Fast Marching Method on 2-D structured uniform grids.

This class enables running a Fast Marching procedure to calculate the signed distance function and extend a given front speed.

### 7.34.2 Constructor & Destructor Documentation

**[FastMarching2D](#) ( const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &ls )**

Constructor using grid and level set function.

Parameters

|    |    |                                                                                                                                                                                                                                                                                                                                              |
|----|----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | g  | Instance of class <a href="#">Grid</a>                                                                                                                                                                                                                                                                                                       |
| in | ls | Vector containing the level set function at grid nodes. The values are 0 on the interface (from which the distance is computed), positive on one side and negative on the other side. They must contain the signed distance on the nodes surrounding the interface but can take any value on other nodes, provided they have the right sign. |

**[FastMarching2D](#) ( const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &ls, [Vect](#)< [real\\_t](#) > &F )**

Constructor using grid, level set function and velocity to extend.

Parameters

|    |      |                                                                                                                                                                                                                                                                                                                                         |
|----|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | $g$  | Instance of class <a href="#">Grid</a>                                                                                                                                                                                                                                                                                                  |
| in | $ls$ | Vector containing the level set function at grid nodes. The values are 0 on the interface (from which the distance is computed), positive on one side and negative on the other side. They must contain the signed distance on the nodes surrounding the interface but can take any value on other nodes, provided their sign is right. |
| in | $F$  | Vector containing the front speed at grid nodes. Only values on nodes surrounding the interface are relevant.                                                                                                                                                                                                                           |

### 7.34.3 Member Function Documentation

**void execute ( )**

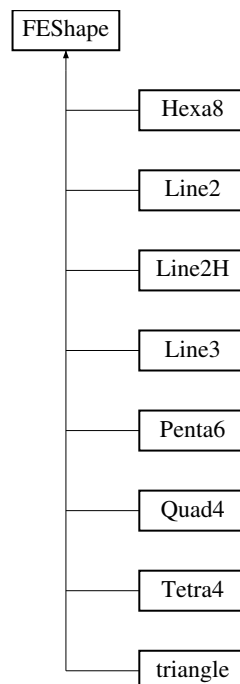
Execute Fast Marching Procedure.

Once this function was called, the vector  $ls$  used in the constructor will contain the signed distance function and  $F$  will contain the extended speed.

## 7.35 FEShape Class Reference

Parent class from which inherit all finite element shape classes.

Inheritance diagram for FEShape:



### Public Member Functions

- [FEShape](#) ( )  
*Default Constructor.*
- [FEShape](#) (const [Element](#) \*el)

- Constructor for an element.*
- **FEShape** (const **Side** \*sd)
- Constructor for a side.*
- virtual **~FEShape** ()
- Destructor.*
- **real.t Sh** (size\_t i) const
- Return shape function of node i at given point.*
- **real.t Sh** (size\_t i, **Point**< **real.t** > s) const
- Calculate shape function of node i at a given point s.*
- **Point**< **real.t** > **DSh** (size\_t i) const
- Return derivatives of shape function of node i at a given point.*
- **real.t getDet** () const
- Return determinant of jacobian.*
- **Point**< **real.t** > **getCenter** () const
- Return coordinates of center of element.*
- **Point**< **real.t** > **getLocalPoint** () const
- Localize a point in the element.*
- **Point**< **real.t** > **getLocalPoint** (const **Point**< **real.t** > &s) const
- Localize a point in the element.*

### 7.35.1 Detailed Description

Parent class from which inherit all finite element shape classes.

### 7.35.2 Constructor & Destructor Documentation

**FEShape** ( const **Element** \* el )

Constructor for an element.

Parameters

|    |    |                    |
|----|----|--------------------|
| in | el | Pointer to element |
|----|----|--------------------|

**FEShape** ( const **Side** \* sd )

Constructor for a side.

Parameters

|    |    |                 |
|----|----|-----------------|
| in | sd | Pointer to side |
|----|----|-----------------|

### 7.35.3 Member Function Documentation

**real.t Sh** ( size\_t i, **Point**< **real.t** > s ) const

Calculate shape function of node i at a given point s.

Parameters

|    |   |                                                                              |
|----|---|------------------------------------------------------------------------------|
| in | i | Local node label                                                             |
| in | s | <b>Point</b> in the reference triangle where the shape function is evaluated |

**Point<real\_t> DSh ( size\_t i ) const**

Return derivatives of shape function of node *i* at a given point.

If the transformation (Reference element -> Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

Parameters

|           |          |                                      |
|-----------|----------|--------------------------------------|
| <i>in</i> | <i>i</i> | Partial derivative index (1, 2 or 3) |
|-----------|----------|--------------------------------------|

**real\_t getDet ( ) const**

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const**

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > &s ) const**

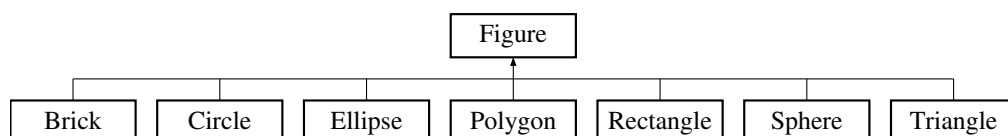
Localize a point in the element.

Return actual coordinates where *s* are coordinates in the reference element.

## 7.36 Figure Class Reference

To store and treat a figure (or shape) information.

Inheritance diagram for Figure:



### Public Member Functions

- `Figure ()`  
*Default constructor.*
- `Figure (const Figure &f)`  
*Copy constructor.*
- `virtual ~Figure ()`  
*Destructor.*
- `void setCode (int code)`  
*Choose a code for the domain defined by the figure.*
- `virtual real_t getSignedDistance (const Point< real_t > &p) const`  
*Return signed distance from a given point to current figure.*
- `Figure & operator= (const Figure &f)`

*Operator =.*

- `void getSignedDistance (const Grid &g, Vect< real\_t > &d) const`  
*Calculate signed distance to current figure with respect to grid points.*
- `real\_t dLine (const Point< real\_t > &p, const Point< real\_t > &a, const Point< real\_t > &b) const`  
*Compute signed distance from a line.*

### 7.36.1 Detailed Description

To store and treat a figure (or shape) information.

This class is essentially useful to construct data for mesh generators and for distance calculations.

### 7.36.2 Member Function Documentation

**virtual [real\\_t](#) getSignedDistance ( const [Point](#)< [real\\_t](#) > & *p* ) const** [virtual]

Return signed distance from a given point to current figure.

Parameters

|    |          |                                                                |
|----|----------|----------------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> instance from which distance is computed |
|----|----------|----------------------------------------------------------------|

Reimplemented in [Polygon](#), [Triangle](#), [Ellipse](#), [Sphere](#), [Circle](#), [Brick](#), and [Rectangle](#).

**void getSignedDistance ( const [Grid](#) &g, [Vect](#)< [real\\_t](#) > & *d* ) const**

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |          |                                                                                                             |
|----|----------|-------------------------------------------------------------------------------------------------------------|
| in | <i>g</i> | <a href="#">Grid</a> instance                                                                               |
| in | <i>d</i> | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector *d* doesn't need to be sized before invoking this function

**[real\\_t](#) dLine ( const [Point](#)< [real\\_t](#) > & *p*, const [Point](#)< [real\\_t](#) > & *a*, const [Point](#)< [real\\_t](#) > & *b* ) const**

Compute signed distance from a line.

Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> for which distance is computed |
| in | <i>a</i> | First vertex of line                                 |
| in | <i>b</i> | Second vertex of line                                |

Returns

Signed distance

## 7.37 FMM2D Class Reference

class for the fast marching 2-D algorithm

Inherits [FMM](#).

## Public Member Functions

- **FMM2D** (const [Grid](#) &g, [Vect](#)< [real\\_t](#) > \*phi, bool HA)

*Constructor.*

- void **InitHeap** (Heap &NarrowPt)
- void **solve** ()

*Execute Fast Marching Procedure.*

- void **Evaluate** (IPoint &pt, int sign)  
*compute the distance from node to interface*
- void **ExtendSpeed** ([Vect](#)< [real\\_t](#) > &F)

*Extend the speed function to the whole grid.*

- [real\\_t](#) **check\_error** ()

*Check error by comparing with the gradient norm.*

### 7.37.1 Detailed Description

class for the fast marching 2-D algorithm

This class manages the 2-D Fast Marching method

### 7.37.2 Constructor & Destructor Documentation

**FMM2D** ( const [Grid](#) &g, [Vect](#)< [real\\_t](#) > \*phi, bool HA )

Constructor.

Parameters

|    |            |                                                                                                                                                                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>g</i>   | Instance of class <a href="#">Grid</a>                                                                                                                                                                                                                                                                                                       |
| in | <i>phi</i> | Vector containing the level set function at grid nodes. The values are 0 on the interface (from which the distance is computed), positive on one side and negative on the other side. They must contain the signed distance on the nodes surrounding the interface but can take any value on other nodes, provided they have the right sign. |
| in | <i>HA</i>  | true if the program must be executed with high accuracy, false otherwise                                                                                                                                                                                                                                                                     |

### 7.37.3 Member Function Documentation

**void InitHeap** ( Heap & *NarrowPt* )

Initialize the heap

Parameters

|        |                 |                               |
|--------|-----------------|-------------------------------|
| in,out | <i>NarrowPt</i> | Heap containing Narrow points |
|--------|-----------------|-------------------------------|

**void Evaluate** ( IPoint & *pt*, int *sign* )

compute the distance from node to interface



Parameters

|    |             |                           |
|----|-------------|---------------------------|
| in | <i>pt</i>   | node to treat             |
| in | <i>sign</i> | <a href="#">Node</a> sign |

Returns

distance from node *pt* to interface

**void ExtendSpeed ( Vect< real.t > &F )**

Extend the speed function to the whole grid.

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>F</i> | Vector containing the speed at interface nodes on input and extended speed to all grid nodes |
|--------|----------|----------------------------------------------------------------------------------------------|

**real.t check\_error ( )**

Check error by comparing with the gradient norm.

This function returns discrete  $L^2$  and Max. errors

## 7.38 FMM3D Class Reference

class for the 3-D fast marching algorithm

Inherits FMM.

### Public Member Functions

- [FMM3D](#) (const [Grid](#) &g, Vect< real.t > \*phi, bool HA)  
*Constructor.*
- void [InitHeap](#) (Heap &NarrowPt)  
*Initialize heap.*
- void [solve](#) ()  
*Execute Fast Marching Procedure.*
- void [Evaluate](#) (IPoint &pt, int sign)  
*Compute the distance from node to interface.*
- void [ExtendSpeed](#) (Vect< real.t > &F)  
*Extend the speed function to the whole grid.*
- [real.t check\\_error](#) ()  
*Check error by comparing with the gradient norm.*

### 7.38.1 Detailed Description

class for the 3-D fast marching algorithm

This class manages the 3-D Fast Marching Method

### 7.38.2 Constructor & Destructor Documentation

**FMM3D ( const Grid &g, Vect< real.t > \*phi, bool HA )**

Constructor.

Parameters

|    |        |                                                                                                                                                                                                                                                                                                                                              |
|----|--------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | $g$    | Instance of class <a href="#">Grid</a>                                                                                                                                                                                                                                                                                                       |
| in | $\phi$ | Vector containing the level set function at grid nodes. The values are 0 on the interface (from which the distance is computed), positive on one side and negative on the other side. They must contain the signed distance on the nodes surrounding the interface but can take any value on other nodes, provided they have the right sign. |
| in | $HA$   | true if the program must be executed with high accuracy, false otherwise                                                                                                                                                                                                                                                                     |

### 7.38.3 Member Function Documentation

**void InitHeap ( Heap & NarrowPt )**

Initialize heap.

Parameters

|                 |  |
|-----------------|--|
| <i>NarrowPt</i> |  |
|-----------------|--|

**void Evaluate ( IPoint & pt, int sign )**

Compute the distance from node to interface.

Parameters

|    |        |                 |
|----|--------|-----------------|
| in | $pt$   | node to treat   |
| in | $sign$ | the node's sign |

Returns

distance from node pt to interface

**void ExtendSpeed ( Vect< real.t > & F )**

Extend the speed function to the whole grid.

Parameters

|        |     |                                                                                                |
|--------|-----|------------------------------------------------------------------------------------------------|
| in,out | $F$ | Vector containing the speed at interface nodes on input and extended speed at whole grid nodes |
|--------|-----|------------------------------------------------------------------------------------------------|

**real.t check\_error ( )**

Check error by comparing with the gradient norm.

This function prints discrete  $L^2$  and Max. errors

## 7.39 FMMSolver Class Reference

The Fast Marching Method solver.

## Public Member Functions

- **FMMSolver** (const **Grid** &g, **Vect**< **real.t** > &phi, bool ha=false)  
*Constructor.*
- **~FMMSolver** ()  
*Destructor.*
- void **solve** ()  
*Execute the fast marching program.*
- void **ExtendSpeed** (**Vect**< **real.t** > &F)  
*Extend speed by Sethian's method.*
- **real.t** **check\_error** ()  
*Return the consistency error of the method.*

### 7.39.1 Detailed Description

The Fast Marching Method solver.

This class enables computing the signed distance function with respect to an interface. It works in 2-D and 3-D on a structured grid. The class is an interface for client. It points to FMM

### 7.39.2 Constructor & Destructor Documentation

**FMMSolver** ( const **Grid** &g, **Vect**< **real.t** > &phi, bool ha = false )

Constructor.  
Parameters

|    |     |                                                                                                                                                                                                                                                                                                                                                                                                                                                 |
|----|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | g   | Instance of class <b>Grid</b> defining the grid on which the distance is computed.                                                                                                                                                                                                                                                                                                                                                              |
| in | phi | Vector containing the level set function at grid nodes. The vector entries are 0 on the interface (from which the distance is computed), positive on one side and negative on the other side. They must contain the signed distance on the nodes surrounding the interface. These values identify by linear interpolation the interface position. The vector entries can take any value on other grid nodes, provided they have the right sign. |
| in | ha  | true if high accuracy FMM is active. The high accuracy version is more accurate but requires more accurate values on the nodes neighbouring the interface.                                                                                                                                                                                                                                                                                      |

### 7.39.3 Member Function Documentation

**void ExtendSpeed** ( **Vect**< **real.t** > &F )

Extend speed by Sethian's method.

The method consists in calculating a speed F such that its gradient is orthogonal to the gradient of the level set function

Parameters

|         |   |                                                                                                                                 |
|---------|---|---------------------------------------------------------------------------------------------------------------------------------|
| in, out | F | Speed function where on input the value of the function is meaningful on the interface. On output F contains the extended speed |
|---------|---|---------------------------------------------------------------------------------------------------------------------------------|

**real.t check\_error ( )**

Return the consistency error of the method.

Consistency is measured by computing the discrete value of the norm of the gradient of the signed distance and subtracting the obtained norm from 1. The absolute value of the result is returned.

## 7.40 Funct Class Reference

A simple class to parse real valued functions.

### Public Member Functions

- **Funct** ()  
*Default constructor.*
- **Funct** (string v)  
*Constructor for a function of one variable.*
- **Funct** (string v1, string v2)  
*Constructor for a function of two variables.*
- **Funct** (string v1, string v2, string v3)  
*Constructor for a function of three variables.*
- **Funct** (string v1, string v2, string v3, string v4)  
*Constructor for a function of four variables.*
- **~Funct** ()  
*Destructor.*
- **real.t operator()** (real.t x) const  
*Operator () to evaluate the function with one variable  $x$*
- **real.t operator()** (real.t x, real.t y) const  
*Operator () to evaluate the function with two variables  $x, y$*
- **real.t operator()** (real.t x, real.t y, real.t z) const  
*Operator () to evaluate the function with three variables  $x, y, z$*
- **real.t operator()** (real.t x, real.t y, real.t z, real.t t) const  
*Operator () to evaluate the function with four variables  $x, y, z$*
- **void operator=** (string e)  
*Operator =.*

### 7.40.1 Detailed Description

A simple class to parse real valued functions.

Functions must have 1, 2, 3 or at most 4 variables.

Warning

Data in the file must be listed in the following order:

```
for x=x_0,...,x_I
 for y=y_0,...,y_J
 for z=z_0,...,z_K
 read v(x,y,z)
```

### 7.40.2 Constructor & Destructor Documentation

#### **Funct ( string v )**

Constructor for a function of one variable.

Parameters

|                 |                |                      |
|-----------------|----------------|----------------------|
| <code>in</code> | <code>v</code> | Name of the variable |
|-----------------|----------------|----------------------|

**Func ( string *v1*, string *v2* )**

Constructor for a function of two variables.

Parameters

|                 |                 |                             |
|-----------------|-----------------|-----------------------------|
| <code>in</code> | <code>v1</code> | Name of the first variable  |
| <code>in</code> | <code>v2</code> | Name of the second variable |

**Func ( string *v1*, string *v2*, string *v3* )**

Constructor for a function of three variables.

Parameters

|                 |                 |                             |
|-----------------|-----------------|-----------------------------|
| <code>in</code> | <code>v1</code> | Name of the first variable  |
| <code>in</code> | <code>v2</code> | Name of the second variable |
| <code>in</code> | <code>v3</code> | Name of the third variable  |

**Func ( string *v1*, string *v2*, string *v3*, string *v4* )**

Constructor for a function of four variables.

Parameters

|                 |                 |                             |
|-----------------|-----------------|-----------------------------|
| <code>in</code> | <code>v1</code> | Name of the first variable  |
| <code>in</code> | <code>v2</code> | Name of the second variable |
| <code>in</code> | <code>v3</code> | Name of the third variable  |
| <code>in</code> | <code>v4</code> | Name of the fourth variable |

### 7.40.3 Member Function Documentation

**void operator= ( string *e* )**

Operator =.

Define the function by an algebraic expression following regexp rules

Parameters

|                 |                |                                             |
|-----------------|----------------|---------------------------------------------|
| <code>in</code> | <code>e</code> | Algebraic expression defining the function. |
|-----------------|----------------|---------------------------------------------|

## 7.41 Gauss Class Reference

Calculate data for Gauss integration.

### Public Member Functions

- [Gauss](#) ()  
*Default constructor.*
- [Gauss](#) (size\_t np)  
*Constructor using number of [Gauss](#) points.*
- void [setTriangle](#) (LocalVect< real.t, 7 > &w, LocalVect< Point< real.t >, 7 > &x)

*Choose integration on triangle (7-point formula)*

- `real_t x (size_t i) const`  
*Return coordinate of  $i$ -th Gauss-Legendre point.*
- `const Point< real_t > & xt (size_t i) const`  
*Return coordinates of points in the reference triangle.*
- `real_t w (size_t i) const`  
*Return weight of  $i$ -th Gauss-Legendre point.*

### 7.41.1 Detailed Description

Calculate data for Gauss integration.

### 7.41.2 Member Function Documentation

`void setTriangle ( LocalVect< real_t, 7 > & w, LocalVect< Point< real_t >, 7 > & x )`

*Choose integration on triangle (7-point formula)*

If this is not selected, `Gauss` integration formula on  $[-1, 1]$  is calculated.

## 7.42 Grid Class Reference

To manipulate structured grids.

### Public Member Functions

- `Grid ()`  
*Construct a default grid with 10 intervals in each direction.*
- `Grid (real_t xm, real_t xM, size_t npX)`  
*Construct a 1-D structured grid given its extremal coordinates and number of intervals.*
- `Grid (real_t xm, real_t xM, real_t ym, real_t yM, size_t npX, size_t npY)`  
*Construct a 2-D structured grid given its extremal coordinates and number of intervals.*
- `Grid (Point< real_t > m, Point< real_t > M, size_t npX, size_t npY)`  
*Construct a 2-D structured grid given its extremal coordinates and number of intervals.*
- `Grid (real_t xm, real_t xM, real_t ym, real_t yM, real_t zm, real_t zM, size_t npX, size_t npY, size_t npZ)`  
*Construct a 3-D structured grid given its extremal coordinates and number of intervals.*
- `Grid (Point< real_t > m, Point< real_t > M, size_t npX, size_t npY, size_t npZ)`  
*Construct a 3-D structured grid given its extremal coordinates and number of intervals.*
- `void setXMin (const Point< real_t > &x)`  
*Set min. coordinates of the domain.*
- `void setXMax (const Point< real_t > &x)`
- `void setDomain (real_t xmin, real_t xmax)`  
*Set Dimensions of the domain: 1-D case.*
- `void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax)`  
*Set Dimensions of the domain: 2-D case.*
- `void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax, real_t zmin, real_t zmax)`  
*Set Dimensions of the domain: 3-D case.*
- `void setDomain (Point< real_t > xmin, Point< real_t > xmax)`  
*Set Dimensions of the domain: 3-D case.*

- `const Point< real_t > & getXMin () const`  
Return min. Coordinates of the domain.
- `const Point< real_t > & getXMax () const`  
Return max. Coordinates of the domain.
- `void setN (size_t nx, size_t ny=0, size_t nz=0)`  
Set number of grid intervals in the  $x$ ,  $y$  and  $z$ -directions.
- `size_t getNx () const`  
Return number of grid intervals in the  $x$ -direction.
- `size_t getNy () const`  
Return number of grid intervals in the  $y$ -direction.
- `size_t getNz () const`  
Return number of grid intervals in the  $z$ -direction.
- `real_t getHx () const`  
Return grid size in the  $x$ -direction.
- `real_t getHy () const`  
Return grid size in the  $y$ -direction.
- `real_t getHz () const`  
Return grid size in the  $z$ -direction.
- `Point< real_t > getCoord (size_t i) const`  
Return coordinates a point with label  $i$  in a 1-D grid.
- `Point< real_t > getCoord (size_t i, size_t j) const`  
Return coordinates a point with label  $(i, j)$  in a 2-D grid.
- `Point< real_t > getCoord (size_t i, size_t j, size_t k) const`  
Return coordinates a point with label  $(i, j, k)$  in a 3-D grid.
- `real_t getX (size_t i) const`  
Return  $x$ -coordinate of point with index  $i$
- `real_t getY (size_t j) const`  
Return  $y$ -coordinate of point with index  $j$
- `real_t getZ (size_t k) const`  
Return  $z$ -coordinate of point with index  $k$
- `Point2D< real_t > getXY (size_t i, size_t j) const`  
Return coordinates of point with indices  $(i, j)$
- `Point< real_t > getXYZ (size_t i, size_t j, size_t k) const`  
Return coordinates of point with indices  $(i, j, k)$
- `real_t getCenter (size_t i) const`  
Return coordinates of center of a 1-D cell with indices  $i, i+1$
- `Point< real_t > getCenter (size_t i, size_t j) const`  
Return coordinates of center of a 2-D cell with indices  $(i, j), (i+1, j), (i+1, j+1), (i, j+1)$
- `Point< real_t > getCenter (size_t i, size_t j, size_t k) const`  
Return coordinates of center of a 3-D cell with indices  $(i, j, k), (i+1, j, k), (i+1, j+1, k), (i, j+1, k), (i, j, k+1), (i+1, j, k+1), (i+1, j+1, k+1), (i, j+1, k+1)$
- `void setCode (string exp, int code)`  
Set a code for some grid points.
- `void setCode (int side, int code)`  
Set a code for grid points on sides.
- `int getCode (int side) const`  
Return code for a side number.

- `int getCode (size_t i, size_t j) const`  
*Return code for a grid point.*
- `int getCode (size_t i, size_t j, size_t k) const`  
*Return code for a grid point.*
- `size_t getDim () const`  
*Return space dimension.*
- `void Deactivate (size_t i)`  
*Change state of a cell from active to inactive (1-D grid)*
- `void Deactivate (size_t i, size_t j)`  
*Change state of a cell from active to inactive (2-D grid)*
- `void Deactivate (size_t i, size_t j, size_t k)`  
*Change state of a cell from active to inactive (2-D grid)*
- `int isActive (size_t i) const`  
*Say if cell is active or not (1-D grid)*
- `int isActive (size_t i, size_t j) const`  
*Say if cell is active or not (2-D grid)*
- `int isActive (size_t i, size_t j, size_t k) const`  
*Say if cell is active or not (3-D grid)*

### 7.42.1 Detailed Description

To manipulate structured grids.

### 7.42.2 Constructor & Destructor Documentation

**Grid ( real\_t xm, real\_t xM, size\_t npx )**

Construct a 1-D structured grid given its extremal coordinates and number of intervals.

Parameters

|                 |                  |                                             |
|-----------------|------------------|---------------------------------------------|
| <code>in</code> | <code>xm</code>  | Minimal value for x                         |
| <code>in</code> | <code>xM</code>  | Maximal value for x                         |
| <code>in</code> | <code>npx</code> | Number of grid intervals in the x-direction |

**Grid ( real\_t xm, real\_t xM, real\_t ym, real\_t yM, size\_t npx, size\_t npy )**

Construct a 2-D structured grid given its extremal coordinates and number of intervals.

Parameters

|                 |                  |                                             |
|-----------------|------------------|---------------------------------------------|
| <code>in</code> | <code>xm</code>  | Minimal value for x                         |
| <code>in</code> | <code>xM</code>  | Maximal value for x                         |
| <code>in</code> | <code>ym</code>  | Minimal value for y                         |
| <code>in</code> | <code>yM</code>  | Maximal value for y                         |
| <code>in</code> | <code>npx</code> | Number of grid intervals in the x-direction |
| <code>in</code> | <code>npy</code> | Number of grid intervals in the y-direction |

**Grid ( Point< real\_t > m, Point< real\_t > M, size\_t npx, size\_t npy )**

Construct a 2-D structured grid given its extremal coordinates and number of intervals.



Parameters

|                 |                  |                                             |
|-----------------|------------------|---------------------------------------------|
| <code>in</code> | <code>m</code>   | Minimal coordinate value                    |
| <code>in</code> | <code>M</code>   | Maximal coordinate value                    |
| <code>in</code> | <code>npx</code> | Number of grid intervals in the x-direction |
| <code>in</code> | <code>npz</code> | Number of grid intervals in the y-direction |

**Grid ( `real_t xm`, `real_t xM`, `real_t ym`, `real_t yM`, `real_t zm`, `real_t zM`, `size_t npx`, `size_t npy`, `size_t npz` )**

Construct a 3-D structured grid given its extremal coordinates and number of intervals.

Parameters

|                 |                  |                                             |
|-----------------|------------------|---------------------------------------------|
| <code>in</code> | <code>xm</code>  | Minimal value for x                         |
| <code>in</code> | <code>xM</code>  | Maximal value for x                         |
| <code>in</code> | <code>ym</code>  | Minimal value for y                         |
| <code>in</code> | <code>yM</code>  | Maximal value for y                         |
| <code>in</code> | <code>zm</code>  | Minimal value for z                         |
| <code>in</code> | <code>zM</code>  | Maximal value for z                         |
| <code>in</code> | <code>npx</code> | Number of grid intervals in the x-direction |
| <code>in</code> | <code>npy</code> | Number of grid intervals in the y-direction |
| <code>in</code> | <code>npz</code> | Number of grid intervals in the z-direction |

**Grid ( `Point< real_t > m`, `Point< real_t > M`, `size_t npx`, `size_t npy`, `size_t npz` )**

Construct a 3-D structured grid given its extremal coordinates and number of intervals.

Parameters

|                 |                  |                                             |
|-----------------|------------------|---------------------------------------------|
| <code>in</code> | <code>m</code>   | Minimal coordinate value                    |
| <code>in</code> | <code>M</code>   | Maximal coordinate value                    |
| <code>in</code> | <code>npx</code> | Number of grid intervals in the x-direction |
| <code>in</code> | <code>npy</code> | Number of grid intervals in the y-direction |
| <code>in</code> | <code>npz</code> | Number of grid intervals in the z-direction |

### 7.42.3 Member Function Documentation

**void setXMin ( `const Point< real_t > &x` )**

Set min. coordinates of the domain.

Parameters

|                 |                |                               |
|-----------------|----------------|-------------------------------|
| <code>in</code> | <code>x</code> | Minimal values of coordinates |
|-----------------|----------------|-------------------------------|

**void setXMax ( `const Point< real_t > &x` )**

Set max. coordinates of the domain.

Parameters

|                 |                |                               |
|-----------------|----------------|-------------------------------|
| <code>in</code> | <code>x</code> | Maximal values of coordinates |
|-----------------|----------------|-------------------------------|

**void setDomain ( `real_t xmin`, `real_t xmax` )**

Set Dimensions of the domain: 1-D case.

Parameters

|                 |                   |                               |
|-----------------|-------------------|-------------------------------|
| <code>in</code> | <code>xmin</code> | Minimal value of x-coordinate |
| <code>in</code> | <code>xmax</code> | Maximal value of x-coordinate |

**void setDomain ( `real_t xmin`, `real_t xmax`, `real_t ymin`, `real_t ymax` )**

Set Dimensions of the domain: 2-D case.

Parameters

|                 |                   |                               |
|-----------------|-------------------|-------------------------------|
| <code>in</code> | <code>xmin</code> | Minimal value of x-coordinate |
| <code>in</code> | <code>xmax</code> | Maximal value of x-coordinate |
| <code>in</code> | <code>ymin</code> | Minimal value of y-coordinate |
| <code>in</code> | <code>ymax</code> | Maximal value of y-coordinate |

**void setDomain ( `real_t xmin`, `real_t xmax`, `real_t ymin`, `real_t ymax`, `real_t zmin`, `real_t zmax` )**

Set Dimensions of the domain: 3-D case.

Parameters

|                 |                   |                               |
|-----------------|-------------------|-------------------------------|
| <code>in</code> | <code>xmin</code> | Minimal value of x-coordinate |
| <code>in</code> | <code>xmax</code> | Maximal value of x-coordinate |
| <code>in</code> | <code>ymin</code> | Minimal value of y-coordinate |
| <code>in</code> | <code>ymax</code> | Maximal value of y-coordinate |
| <code>in</code> | <code>zmin</code> | Minimal value of z-coordinate |
| <code>in</code> | <code>zmax</code> | Maximal value of z-coordinate |

**void setDomain ( `Point< real_t > xmin`, `Point< real_t > xmax` )**

Set Dimensions of the domain: 3-D case.

Parameters

|                 |                   |                          |
|-----------------|-------------------|--------------------------|
| <code>in</code> | <code>xmin</code> | Minimal coordinate value |
| <code>in</code> | <code>xmax</code> | Maximal coordinate value |

**void setN ( `size_t nx`, `size_t ny = 0`, `size_t nz = 0` )**

Set number of grid intervals in the x, y and z-directions.

Number of points is the number of intervals plus one in each direction

Parameters

|                 |                 |                                                                          |
|-----------------|-----------------|--------------------------------------------------------------------------|
| <code>in</code> | <code>nx</code> | Number of grid intervals in the x-direction                              |
| <code>in</code> | <code>ny</code> | Number of grid intervals in the y-direction (Default=0: 1-D grid)        |
| <code>in</code> | <code>nz</code> | Number of grid intervals in the z-direction (Default=0: 1-D or 2-D grid) |

Remarks

: The size of the grid (`xmin` and `xmax`) must have been defined before.

**size\_t getNy ( ) const**

Return number of grid intervals in the y-direction.  
 ny=0 for 1-D domains (segments)

**size\_t getNz ( ) const**

Return number of grid intervals in the z-direction.  
 nz=0 for 1-D (segments) and 2-D domains (rectangles)

**void setCode ( string exp, int code )**

Set a code for some grid points.

Parameters

|    |      |                                                                                         |
|----|------|-----------------------------------------------------------------------------------------|
| in | exp  | Regular expression that determines the set of grid points on which the code is applied. |
| in | code | Code to assign.                                                                         |

**void setCode ( int side, int code )**

Set a code for grid points on sides.

Parameters

|    |      |                                                                                                                |
|----|------|----------------------------------------------------------------------------------------------------------------|
| in | side | <a href="#">Side</a> for which code is assigned. Possible values are: MIN_X, MAX_X, MIN_Y, MAX_Y, MIN_Z, MAX_Z |
| in | code | Code to assign.                                                                                                |

**int getCode ( int side ) const**

Return code for a side number.

Parameters

|    |      |                                                                                                                |
|----|------|----------------------------------------------------------------------------------------------------------------|
| in | side | <a href="#">Side</a> for which code is returned. Possible values are: MIN_X, MAX_X, MIN_Y, MAX_Y, MIN_Z, MAX_Z |
|----|------|----------------------------------------------------------------------------------------------------------------|

**int getCode ( size\_t i, size\_t j ) const**

Return code for a grid point.

Parameters

|    |   |                                                       |
|----|---|-------------------------------------------------------|
| in | i | i-th index for node for which code is to be returned. |
| in | j | j-th index for node for which code is to be returned. |

**int getCode ( size\_t i, size\_t j, size\_t k ) const**

Return code for a grid point.

Parameters

|    |   |                                                       |
|----|---|-------------------------------------------------------|
| in | i | i-th index for node for which code is to be returned. |
| in | j | j-th index for node for which code is to be returned. |
| in | k | k-th index for node for which code is to be returned. |

**void Deactivate ( size\_t *i* )**

Change state of a cell from active to inactive (1-D grid)

Parameters

|           |          |                     |
|-----------|----------|---------------------|
| <b>in</b> | <i>i</i> | grid cell to remove |
|-----------|----------|---------------------|

**void Deactivate ( size\_t *i*, size\_t *j* )**

Change state of a cell from active to inactive (2-D grid)

Parameters

|           |          |                                                                                         |
|-----------|----------|-----------------------------------------------------------------------------------------|
| <b>in</b> | <i>i</i> | i-th index for grid cell to remove. If this value is 0, all cells (*,j) are deactivated |
| <b>in</b> | <i>j</i> | j-th index for grid cell to remove If this value is 0, all cells (i,*) are deactivated  |

Remarks

if i and j have value 0 all grid cells are deactivated !!

**void Deactivate ( size\_t *i*, size\_t *j*, size\_t *k* )**

Change state of a cell from active to inactive (2-D grid)

Parameters

|           |          |                                                                                           |
|-----------|----------|-------------------------------------------------------------------------------------------|
| <b>in</b> | <i>i</i> | i-th index for grid cell to remove. If this value is 0, all cells (*,j,k) are deactivated |
| <b>in</b> | <i>j</i> | j-th index for grid cell to remove If this value is 0, all cells (i,*,k) are deactivated  |
| <b>in</b> | <i>k</i> | k-th index for grid cell to remove If this value is 0, all cells (i,j,*) are deactivated  |

**int isActive ( size\_t *i* ) const**

Say if cell is active or not (1-D grid)

Parameters

|           |          |               |
|-----------|----------|---------------|
| <b>in</b> | <i>i</i> | Index of cell |
|-----------|----------|---------------|

Returns

1 if cell is active, 0 if not

**int isActive ( size\_t *i*, size\_t *j* ) const**

Say if cell is active or not (2-D grid)

Parameters

|           |          |                    |
|-----------|----------|--------------------|
| <b>in</b> | <i>i</i> | i-th index of cell |
| <b>in</b> | <i>j</i> | j-th index of cell |

Returns

1 if cell is active, 0 if not

**int isActive ( size\_t *i*, size\_t *j*, size\_t *k* ) const**

Say if cell is active or not (3-D grid)

Parameters

|    |     |                    |
|----|-----|--------------------|
| in | $i$ | i-th index of cell |
| in | $j$ | j-th index of cell |
| in | $k$ | k-th index of cell |

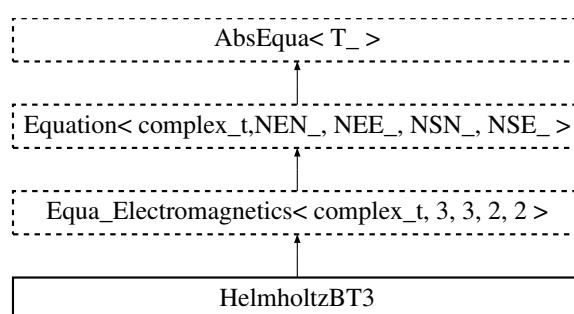
Returns

1 if cell is active, 0 if not

## 7.43 HelmholtzBT3 Class Reference

Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.

Inheritance diagram for HelmholtzBT3:



### Public Member Functions

- [HelmholtzBT3 \(\)](#)  
*Default Constructor.*
- [HelmholtzBT3 \(Element \\*el\)](#)  
*Constructor using element data.*
- [HelmholtzBT3 \(Side \\*sd\)](#)  
*Constructor using side data.*
- [~HelmholtzBT3 \(\)](#)  
*Destructor.*
- void [LHS \(real\\_t wave\\_nb\)](#)  
*Add element Left-Hand Side.*
- void [BoundaryRHS \(UserData< complex\\_t > &ud\)](#)  
*Add element Right-Hand Side using a UserData instance.*
- void [updateBC \(const Element &el, const Vect< T\\_ > &bc\)](#)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC \(const Vect< T\\_ > &bc\)](#)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [DiagBC \(int dof\\_type=NODE.DOF, int dof=0\)](#)  
*Update element matrix to impose bc by diagonalization technique.*
- void [LocalNodeVector \(Vect< T\\_ > &b\)](#)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector \(const Vect< T\\_ > &b, LocalVect< T\\_, NEE\\_ > &be\)](#)  
*Localize Element Vector from a Vect instance.*

- void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be, int dof)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementSideVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NSE\_ > &be)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementVector](#) (const [Vect](#)< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize [Element](#) Vector.*
- void [SideVector](#) (const [Vect](#)< T\_ > &b)  
*Localize [Side](#) Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*

- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > eMat  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > sMat  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > ePrev  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRes  
*[LocalVect](#) instance containing local residual vector associated to current element.*
- [LocalVect](#)< T\_, NSE\_ > sRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current side.*



## Protected Member Functions

- void [MagneticPermeability](#) (const [real\\_t](#) &mu)  
*Set (constant) magnetic permeability.*
- void [MagneticPermeability](#) (const string &exp)  
*Set magnetic permeability given by an algebraic expression.*
- void [ElectricConductivity](#) (const [real\\_t](#) &sigma)  
*Set (constant) electric conductivity.*
- void [ElectricConductivity](#) (const string &exp)  
*set electric conductivity given by an algebraic expression*
- void [ElectricResistivity](#) (const [real\\_t](#) &rho)  
*Set (constant) electric resistivity.*
- void [ElectricResistivity](#) (const string &exp)  
*Set electric resistivity given by an algebraic expression.*
- void [setMaterial](#) ()  
*Set material properties.*
- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.43.1 Detailed Description

Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.  
Problem being formulated in time harmonics, the solution is complex valued.

### 7.43.2 Member Function Documentation

**void updateBC ( const [Element](#) &el, const [Vect](#)< [T\\_](#) > &bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                    |                    |                                                 |
|--------------------|--------------------|-------------------------------------------------|
| <a href="#">in</a> | <a href="#">el</a> | Reference to current element instance           |
| <a href="#">in</a> | <a href="#">bc</a> | Vector that contains imposed values at all DOFs |

**void updateBC ( const [Vect](#)< [T\\_](#) > &bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                    |                    |                                                 |
|--------------------|--------------------|-------------------------------------------------|
| <a href="#">in</a> | <a href="#">bc</a> | Vector that contains imposed values at all DOFs |
|--------------------|--------------------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = [NODE\\_DOF](#), int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

Remarks

Only the degree of freedom is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|  |     |                            |
|--|-----|----------------------------|
|  | $A$ | Reference to global matrix |
|--|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|  |     |                                            |
|--|-----|--------------------------------------------|
|  | $b$ | Reference to global right-hand side vector |
|--|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|          |                                                               |
|----------|---------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real.t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

## Parameters

|    |    |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | ls | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | pc | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

## Parameters

|        |   |                                                                                 |
|--------|---|---------------------------------------------------------------------------------|
| in     | A | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | b | Vector containing right-hand side                                               |
| in,out | x | Vector containing initial guess of solution on input, actual solution on output |

### 7.43.3 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

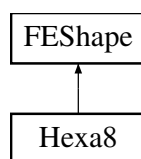
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.44 Hexa8 Class Reference

Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation.

Inheritance diagram for Hexa8:



## Public Member Functions

- **Hexa8** ()  
*Default Constructor.*
- **Hexa8** (const **Element** \*el)  
*Constructor when data of **Element** el are given.*
- **~Hexa8** ()  
*Destructor.*
- void **setLocal** (const **Point**< **real.t** > &s)  
*Initialize local point coordinates in element.*
- **Point**< **real.t** > **DSh** (size\_t i)  
*Return  $x$ ,  $y$  and  $z$  partial derivatives of shape function of node  $i$  at a given point.*
- void **atGauss1** (**LocalVect**< **Point**< **real.t** >, 8 > &dsh, **real.t** &w)  
*Calculate shape function derivatives and integration weights for 1-point **Gauss** rule.*
- void **atGauss2** (**LocalMatrix**< **Point**< **real.t** >, 8, 8 > &dsh, **LocalVect**< **real.t**, 8 > &w)  
*Calculate shape function derivatives and integration weights for 2x2x2-point **Gauss** rule.*
- **real.t** **getMaxEdgeLength** () const  
*Return maximal edge length.*
- **real.t** **getMinEdgeLength** () const  
*Return minimal edge length.*
- **real.t** **Sh** (size\_t i) const  
*Return shape function of node  $i$  at given point.*
- **real.t** **Sh** (size\_t i, **Point**< **real.t** > s) const  
*Calculate shape function of node  $i$  at a given point  $s$ .*
- **Point**< **real.t** > **DSh** (size\_t i) const  
*Return derivatives of shape function of node  $i$  at a given point.*
- **real.t** **getDet** () const  
*Return determinant of jacobian.*
- **Point**< **real.t** > **getCenter** () const  
*Return coordinates of center of element.*
- **Point**< **real.t** > **getLocalPoint** () const  
*Localize a point in the element.*
- **Point**< **real.t** > **getLocalPoint** (const **Point**< **real.t** > &s) const  
*Localize a point in the element.*

### 7.44.1 Detailed Description

Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation.

The reference element is the cube  $[-1, 1] \times [-1, 1] \times [-1, 1]$ . The user must take care to the fact that determinant of jacobian and other quantities depend on the point in the reference element where they are calculated. For this, before any utilization of shape functions or jacobian, function **getLocal(s)** must be invoked.

### 7.44.2 Member Function Documentation

**void setLocal ( const Point< real\_t > & s )**

Initialize local point coordinates in element.

Parameters

|           |          |                                                                                                                                                                                              |
|-----------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <b>s</b> | <a href="#">Point</a> in the reference element This function computes jacobian, shape functions and their partial derivatives at <b>s</b> . Other member functions only return these values. |
|-----------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Point<real\_t> DSh ( size\_t i )**

Return x, y and z partial derivatives of shape function of node **i** at a given point.

Member function *setLocal* must have been called before in order to calculate relevant quantities.

**real\_t Sh ( size\_t i, Point< real\_t > s ) const** [inherited]

Calculate shape function of node **i** at a given point **s**.

Parameters

|           |          |                                                                                       |
|-----------|----------|---------------------------------------------------------------------------------------|
| <b>in</b> | <b>i</b> | Local node label                                                                      |
| <b>in</b> | <b>s</b> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**Point<real\_t> DSh ( size\_t i ) const** [inherited]

Return derivatives of shape function of node **i** at a given point.

If the transformation (Reference element -> Actual element) is not affine, member function *setLocal()* must have been called before in order to calculate relevant quantities.

Parameters

|           |          |                                      |
|-----------|----------|--------------------------------------|
| <b>in</b> | <b>i</b> | Partial derivative index (1, 2 or 3) |
|-----------|----------|--------------------------------------|

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

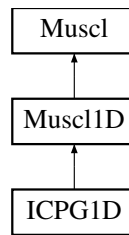
Localize a point in the element.

Return actual coordinates where **s** are coordinates in the reference element.

## 7.45 ICPG1D Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D.

Inheritance diagram for ICPG1D:



## Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum `SolverType` {  
`ROE_SOLVER` = 0,  
`VFROE_SOLVER` = 1,  
`LF_SOLVER` = 2,  
`RUSANOV_SOLVER` = 3,  
`HLL_SOLVER` = 4,  
`HLLC_SOLVER` = 5,  
`MAX_SOLVER` = 6 }

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- `ICPG1D (Mesh &ms)`  
*Constructor using `Mesh` instance.*
- `ICPG1D (Mesh &ms, Vect< real_t > &r, Vect< real_t > &v, Vect< real_t > &p)`  
*Constructor using mesh and initial data.*
- `~ICPG1D ()`  
*Destructor.*
- `void setReconstruction ()`  
*Set reconstruction from class `Muscl`.*
- `real_t runOneTimeStep ()`  
*Advance one time step.*
- `void Forward (const Vect< real_t > &flux, Vect< real_t > &field)`  
*Add flux to field.*
- `void setSolver (SolverType solver)`  
*Choose solver type.*
- `void setGamma (real_t gamma)`

- Set value of constant Gamma for gases.*
- void **setCv** (**real.t** Cv)
  - Set value of Cv (specific heat at constant volume)*
- void **setCp** (**real.t** Cp)
  - Set value of Cp (specific heat at constant pressure)*
- void **setKappa** (**real.t** Kappa)
  - Set value of constant Kappa.*
- **real.t** **getGamma** () const
  - Return value of constant Gamma.*
- **real.t** **getCv** () const
  - Return value of Cv (specific heat at constant volume)*
- **real.t** **getCp** () const
  - Return value of Cp (specific heat at constant pressure)*
- **real.t** **getKappa** () const
  - Return value of constant Kappa.*
- void **getMomentum** (**Vect**< **real.t** > &m) const
  - Get vector of momentum at elements.*
- void **getInternalEnergy** (**Vect**< **real.t** > &ie) const
  - Get vector of internal energy at elements.*
- void **getTotalEnergy** (**Vect**< **real.t** > &te) const
  - Get vector of total energy at elements.*
- void **getSoundSpeed** (**Vect**< **real.t** > &s) const
  - Get vector of sound speed at elements.*
- void **getMach** (**Vect**< **real.t** > &m) const
  - Get vector of elementwise Mach number.*
- void **setInitialCondition\_shock\_tube** (const **LocalVect**< **real.t**, 3 > &BcG, const **LocalVect**< **real.t**, 3 > &BcD, **real.t** x0)
  - Initial condition corresponding to the shock tube.*
- void **setInitialCondition** (const **LocalVect**< **real.t**, 3 > &u)
  - A constant initial condition.*
- void **setBC** (const **Side** &sd, **real.t** u)
  - Assign a boundary condition as a constant to a given side.*
- void **setBC** (int code, **real.t** a)
  - Assign a boundary condition value.*
- void **setBC** (**real.t** a)
  - Assign a boundary condition value.*
- void **setBC** (const **Side** &sd, const **LocalVect**< **real.t**, 3 > &u)
  - Assign a Dirichlet boundary condition vector.*
- void **setBC** (int code, const **LocalVect**< **real.t**, 3 > &U)
  - Assign a Dirichlet boundary condition vector.*
- void **setBC** (const **LocalVect**< **real.t**, 3 > &u)
  - Assign a Dirichlet boundary condition vector.*
- void **setInOutflowBC** (const **Side** &sd, const **LocalVect**< **real.t**, 3 > &u)
  - Impose a constant inflow or outflow boundary condition on a given side.*
- void **setInOutflowBC** (int code, const **LocalVect**< **real.t**, 3 > &u)
  - Impose a constant inflow or outflow boundary condition on sides with a given code.*
- void **setInOutflowBC** (const **LocalVect**< **real.t**, 3 > &u)



*Impose a constant inflow or outflow boundary condition on boundary sides.*

- `real_t getMeanLength ()` const  
*Return mean length.*
- `real_t getMaximumLength ()` const  
*Return maximal length.*
- `real_t getMinimumLength ()` const  
*Return mimal length.*
- `real_t getTauLim ()` const  
*Return mean length.*
- `void print_mesh_stat ()`  
*Output mesh information.*
- `void setTimeStep (real_t dt)`  
*Assign time step value.*
- `real_t getTimeStep ()` const  
*Return time step value.*
- `void setCFL (real_t CFL)`  
*Assign CFL value.*
- `real_t getCFL ()` const  
*Return CFL value.*
- `void setReferenceLength (real_t dx)`  
*Assign reference length value.*
- `real_t getReferenceLength ()` const  
*Return reference length.*
- `Mesh & getMesh ()` const  
*Return reference to *Mesh* instance.*
- `void setVerbose (int v)`  
*Set verbosity parameter.*
- `bool setReconstruction (const Vect< real_t > &U, Vect< real_t > &LU, Vect< real_t > &RU, size_t dof)`  
*Function to reconstruct by the *Muscl* method.*
- `void setMethod (const Method &s)`  
*Choose a flux solver.*
- `void setSolidZoneCode (int c)`  
*Choose a code for solid zone.*
- `bool getSolidZone ()` const  
*Return flag for presence of solid zones.*
- `int getSolidZoneCode ()` const  
*Return code of solid zone, 0 if this one is not present.*
- `void setLimiter (Limiter l)`  
*Choose a flux limiter.*

### 7.45.1 Detailed Description

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D.  
Solution method is a second-order MUSCL Finite Volume scheme

### 7.45.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

*FIRST\_ORDER\_METHOD* First Order upwind method  
*MULTI\_SLOPE\_Q\_METHOD* Multislope Q method  
*MULTI\_SLOPE\_M\_METHOD* Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

*MINMOD\_LIMITER* MinMod limiter  
*VANLEER\_LIMITER* Van Leer limiter  
*SUPERBEE\_LIMITER* Superbee limiter  
*VANALBADA\_LIMITER* Van Albada limiter  
*MAX\_LIMITER* Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

*ROE\_SOLVER* Roe solver  
*VFROE\_SOLVER* Finite Volume Roe solver  
*LF\_SOLVER* LF solver  
*RUSANOV\_SOLVER* Rusanov solver  
*HLL\_SOLVER* HLL solver  
*HLLC\_SOLVER* HLLC solver  
*MAX\_SOLVER* Max solver

### 7.45.3 Constructor & Destructor Documentation

**ICPG1D** ( *Mesh* & *ms*, *Vect*< *real\_t* > & *r*, *Vect*< *real\_t* > & *v*, *Vect*< *real\_t* > & *p* )

Constructor using mesh and initial data.

Parameters

|    |           |                                                  |
|----|-----------|--------------------------------------------------|
| in | <i>ms</i> | Reference to <a href="#">Mesh</a> instance       |
| in | <i>r</i>  | Vector containing initial (elementwise) density  |
| in | <i>v</i>  | Vector containing initial (elementwise) velocity |
| in | <i>p</i>  | Vector containing initial (elementwise) pressure |

### 7.45.4 Member Function Documentation

**void Forward** ( *const Vect*< *real\_t* > & *flux*, *Vect*< *real\_t* > & *field* )

Add flux to field.

If this function is used, the user must call `getFlux` himself

Parameters

|     |              |                                            |
|-----|--------------|--------------------------------------------|
| in  | <i>flux</i>  | Vector containing fluxes at sides (points) |
| out | <i>field</i> | Vector containing solution vector          |

**void getMomentum ( Vect< real.t > & m ) const**

Get vector of momentum at elements.

Parameters

|        |          |                                                                        |
|--------|----------|------------------------------------------------------------------------|
| in,out | <i>m</i> | <a href="#">Vect</a> instance that contains on output element momentum |
|--------|----------|------------------------------------------------------------------------|

**void getInternalEnergy ( Vect< real.t > & ie ) const**

Get vector of internal energy at elements.

Parameters

|        |           |                                                                               |
|--------|-----------|-------------------------------------------------------------------------------|
| in,out | <i>ie</i> | <a href="#">Vect</a> instance that contains on output element internal energy |
|--------|-----------|-------------------------------------------------------------------------------|

**void getTotalEnergy ( Vect< real.t > & te ) const**

Get vector of total energy at elements.

Parameters

|        |           |                                                                            |
|--------|-----------|----------------------------------------------------------------------------|
| in,out | <i>te</i> | <a href="#">Vect</a> instance that contains on output element total energy |
|--------|-----------|----------------------------------------------------------------------------|

**void getSoundSpeed ( Vect< real.t > & s ) const**

Get vector of sound speed at elements.

Parameters

|        |          |                                                                           |
|--------|----------|---------------------------------------------------------------------------|
| in,out | <i>s</i> | <a href="#">Vect</a> instance that contains on output element sound speed |
|--------|----------|---------------------------------------------------------------------------|

**void getMach ( Vect< real.t > & m ) const**

Get vector of elementwise Mach number.

Parameters

|        |          |                                                                           |
|--------|----------|---------------------------------------------------------------------------|
| in,out | <i>m</i> | <a href="#">Vect</a> instance that contains on output element Mach number |
|--------|----------|---------------------------------------------------------------------------|

**void setInitialCondition ( const LocalVect< real.t, 3 > & u )**

A constant initial condition.

Parameters

|    |          |                                                                              |
|----|----------|------------------------------------------------------------------------------|
| in | <i>u</i> | <a href="#">LocalVect</a> instance containing density, velocity and pressure |
|----|----------|------------------------------------------------------------------------------|

**void setBC ( const Side & sd, real.t u )**

Assign a boundary condition as a constant to a given side.

Parameters

|    |           |                                                     |
|----|-----------|-----------------------------------------------------|
| in | <i>sd</i> | <a href="#">Side</a> to which the value is assigned |
| in | <i>u</i>  | Value to assign                                     |

**void setBC ( int *code*, real\_t *a* )**

Assign a boundary condition value.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>code</i> | Code value to which boundary condition is assigned  |
| in | <i>a</i>    | Value to assign to sides that have code <i>code</i> |

**void setBC ( real\_t *a* )**

Assign a boundary condition value.

Parameters

|    |          |                                       |
|----|----------|---------------------------------------|
| in | <i>a</i> | Value to assign to all boundary sides |
|----|----------|---------------------------------------|

**void setBC ( const Side & *sd*, const LocalVect< real\_t, 3 > & *u* )**

Assign a Dirichlet boundary condition vector.

Parameters

|    |           |                                                                               |
|----|-----------|-------------------------------------------------------------------------------|
| in | <i>sd</i> | <a href="#">Side</a> instance to which the values are assigned                |
| in | <i>u</i>  | <a href="#">LocalVect</a> instance that contains values to assign to the side |

**void setBC ( int *code*, const LocalVect< real\_t, 3 > & *U* )**

Assign a Dirichlet boundary condition vector.

Parameters

|    |             |                                                                                                  |
|----|-------------|--------------------------------------------------------------------------------------------------|
| in | <i>code</i> | <a href="#">Side</a> code for which the values are assigned                                      |
| in | <i>U</i>    | <a href="#">LocalVect</a> instance that contains values to assign to sides with code <i>code</i> |

**void setBC ( const LocalVect< real\_t, 3 > & *u* )**

Assign a Dirichlet boundary condition vector.

Parameters

|    |          |                                                                                         |
|----|----------|-----------------------------------------------------------------------------------------|
| in | <i>u</i> | <a href="#">LocalVect</a> instance that contains values to assign to all boundary sides |
|----|----------|-----------------------------------------------------------------------------------------|

**void setInOutflowBC ( const Side & *sd*, const LocalVect< real\_t, 3 > & *u* )**

Impose a constant inflow or outflow boundary condition on a given side.

Parameters

|                 |                 |                                                                               |
|-----------------|-----------------|-------------------------------------------------------------------------------|
| <code>in</code> | <code>sd</code> | Instance of <a href="#">Side</a> on which the condition is prescribed         |
| <code>in</code> | <code>u</code>  | <a href="#">LocalVect</a> instance that contains values to assign to the side |

**void setInOutflowBC ( int *code*, const LocalVect< real.t, 3 > & *u* )**

Impose a constant inflow or outflow boundary condition on sides with a given code.

Parameters

|                 |                   |                                                                                |
|-----------------|-------------------|--------------------------------------------------------------------------------|
| <code>in</code> | <code>code</code> | Value of code for which the condition is prescribed                            |
| <code>in</code> | <code>u</code>    | <a href="#">LocalVect</a> instance that contains values to assign to the sides |

**void setInOutflowBC ( const LocalVect< real.t, 3 > & *u* )**

Impose a constant inflow or outflow boundary condition on boundary sides.

Parameters

|                 |                |                                                                                |
|-----------------|----------------|--------------------------------------------------------------------------------|
| <code>in</code> | <code>u</code> | <a href="#">LocalVect</a> instance that contains values to assign to the sides |
|-----------------|----------------|--------------------------------------------------------------------------------|

**void setTimeStep ( real.t *dt* )** [inherited]

Assign time step value.

Parameters

|                 |                 |                 |
|-----------------|-----------------|-----------------|
| <code>in</code> | <code>dt</code> | Time step value |
|-----------------|-----------------|-----------------|

**void setCFL ( real.t *CFL* )** [inherited]

Assign CFL value.

Parameters

|                 |                  |              |
|-----------------|------------------|--------------|
| <code>in</code> | <code>CFL</code> | Value of CFL |
|-----------------|------------------|--------------|

**void setReferenceLength ( real.t *dx* )** [inherited]

Assign reference length value.

Parameters

|                 |                 |                           |
|-----------------|-----------------|---------------------------|
| <code>in</code> | <code>dx</code> | Value of reference length |
|-----------------|-----------------|---------------------------|

**void setVerbose ( int *v* )** [inherited]

Set verbosity parameter.

Parameters

|                 |                |                              |
|-----------------|----------------|------------------------------|
| <code>in</code> | <code>v</code> | Value of verbosity parameter |
|-----------------|----------------|------------------------------|

**bool setReconstruction ( const Vect< real.t > & *U*, Vect< real.t > & *LU*, Vect< real.t > & *RU*, size.t *dof* )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void setMethod ( const Method & s )** [inherited]

Choose a flux solver.

Parameters

|    |     |                  |
|----|-----|------------------|
| in | $s$ | Solver to choose |
|----|-----|------------------|

**void setLimiter ( Limiter l )** [inherited]

Choose a flux limiter.

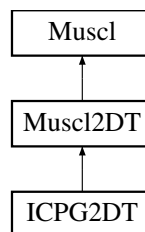
Parameters

|    |     |                   |
|----|-----|-------------------|
| in | $l$ | Limiter to choose |
|----|-----|-------------------|

## 7.46 ICPG2DT Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D.

Inheritance diagram for ICPG2DT:



### Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum SolverType {  
ROE\_SOLVER = 0,  
VFROE\_SOLVER = 1,  
LF\_SOLVER = 2,  
RUSANOV\_SOLVER = 3,  
HLL\_SOLVER = 4,  
HLLC\_SOLVER = 5,  
MAX\_SOLVER = 6 }

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- ICPG2DT (Mesh &ms)  
*Constructor using mesh instance.*
- ICPG2DT (Mesh &ms, Vect< real.t > &r, Vect< real.t > &v, Vect< real.t > &p)  
*Constructor using mesh and initial data.*
- ~ICPG2DT ()  
*Destructor.*
- void setReconstruction ()  
*Reconstruct.*
- real.t runOneTimeStep ()  
*Advance one time step.*
- void Forward (const Vect< real.t > &Flux, Vect< real.t > &Field)  
*Add Flux to Field.*
- real.t getFlux ()  
*Get flux.*
- void setSolver (SolverType s)  
*Choose solver.*
- void setGamma (real.t gamma)  
*Set Gamma value.*
- void setCv (real.t Cv)  
*Set value of heat capacity at constant volume.*
- void setCp (real.t Cp)  
*Set value of heat capacity at constant pressure.*
- void setKappa (real.t Kappa)  
*Set Kappa value.*
- real.t getGamma () const  
*Return value of Gamma.*
- real.t getCv () const  
*Return value of heat capacity at constant volume.*
- real.t getCp () const  
*Return value of heat capacity at constant pressure.*
- real.t getKappa () const  
*Return value of Kappa.*
- Mesh & getMesh ()  
*Return reference to mesh instance.*
- void getMomentum (Vect< real.t > &m) const  
*Calculate elementwise momentum.*

- void `getInternalEnergy` (`Vect< real.t > &e`) const  
*Calculate elementwise internal energy.*
- void `getTotalEnergy` (`Vect< real.t > &e`) const  
*Return elementwise total energy.*
- void `getSoundSpeed` (`Vect< real.t > &s`) const  
*Return elementwise sound speed.*
- void `getMach` (`Vect< real.t > &m`) const  
*Return elementwise Mach number.*
- void `setBC` (const `Side` &sd, `real.t` a)  
*Prescribe a constant boundary condition at given side.*
- void `setBC` (int code, `real.t` a)  
*Prescribe a constant boundary condition for a given code.*
- void `setBC` (`real.t` u)  
*Prescribe a constant boundary condition on all boundary sides.*
- void `setBC` (const `Side` &sd, const `LocalVect< real.t, 4 > &u`)  
*Prescribe a constant boundary condition at a given side.*
- void `setBC` (int code, const `LocalVect< real.t, 4 > &u`)  
*Prescribe a constant boundary condition for a given code.*
- void `setBC` (const `LocalVect< real.t, 4 > &u`)  
*Prescribe a constant boundary condition at all boundary sides.*
- `real.t` `getR` (size\_t i) const  
*Return density at given element label.*
- `real.t` `getV` (size\_t i, size\_t j) const
- `real.t` `getP` (size\_t i) const  
*Return pressure at given element label.*
- bool `setReconstruction` (const `Vect< real.t > &U`, `Vect< real.t > &LU`, `Vect< real.t > &RU`, size\_t dof)  
*Function to reconstruct by the `Muscl` method.*
- void `setTimeStep` (`real.t` dt)  
*Assign time step value.*
- `real.t` `getTimeStep` () const  
*Return time step value.*
- void `setCFL` (`real.t` CFL)  
*Assign CFL value.*
- `real.t` `getCFL` () const  
*Return CFL value.*
- void `setReferenceLength` (`real.t` dx)  
*Assign reference length value.*
- `real.t` `getReferenceLength` () const  
*Return reference length.*
- `Mesh` & `getMesh` () const  
*Return reference to `Mesh` instance.*
- void `setVerbose` (int v)  
*Set verbosity parameter.*
- void `setMethod` (const `Method` &s)  
*Choose a flux solver.*
- void `setSolidZoneCode` (int c)



- *Choose a code for solid zone.*  
 • bool `getSolidZone ()` const  
*Return flag for presence of solid zones.*
- int `getSolidZoneCode ()` const  
*Return code of solid zone, 0 if this one is not present.*
- void `setLimiter (Limiter l)`  
*Choose a flux limiter.*

## Protected Member Functions

- void `Initialize ()`  
*Construction of normals to sides.*

### 7.46.1 Detailed Description

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D.  
 Solution method is a second-order MUSCL Finite Volume scheme on triangles

### 7.46.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

*FIRST\_ORDER\_METHOD* First Order upwind method  
*MULTI\_SLOPE\_Q\_METHOD* Multislope Q method  
*MULTI\_SLOPE\_M\_METHOD* Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

*MINMOD\_LIMITER* MinMod limiter  
*VANLEER\_LIMITER* Van Leer limiter  
*SUPERBEE\_LIMITER* Superbee limiter  
*VANALBADA\_LIMITER* Van Albada limiter  
*MAX\_LIMITER* Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

*ROE\_SOLVER* Roe solver  
*VFROE\_SOLVER* Finite Volume Roe solver  
*LF\_SOLVER* LF solver  
*RUSANOV\_SOLVER* Rusanov solver  
*HLL\_SOLVER* HLL solver  
*HLLC\_SOLVER* HLLC solver  
*MAX\_SOLVER* Max solver

**7.46.3 Constructor & Destructor Documentation**

**ICPG2DT ( Mesh & *ms*, Vect< real\_t > & *r*, Vect< real\_t > & *v*, Vect< real\_t > & *p* )**

Constructor using mesh and initial data.

Parameters

|    |           |                                                                |
|----|-----------|----------------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance                                  |
| in | <i>r</i>  | Initial density vector (as instance of <a href="#">Vect</a> )  |
| in | <i>v</i>  | Initial velocity vector (as instance of <a href="#">Vect</a> ) |
| in | <i>p</i>  | Initial pressure vector (as instance of <a href="#">Vect</a> ) |

### 7.46.4 Member Function Documentation

**void setReconstruction ( )**

Reconstruct.

exit(3) if reconstruction fails

**void Forward ( const Vect< real\_t > & Flux, Vect< real\_t > & Field )**

Add Flux to Field.

If this function is used, the function getFlux must be called

**void setSolver ( SolverType s )**

Choose solver.

Parameters

|    |          |                                                                                                                                                                      |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>s</i> | Index of solver in the enumerated variable SolverType Available values are: ROE_SOLVER, VFROE_SOLVER, LF_SOLVER, RUSANOV_SOLVER, HLL_SOLVER, HLLC_SOLVER, MAX_SOLVER |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void setBC ( const Side & sd, real\_t a )**

Prescribe a constant boundary condition at given side.

Parameters

|    |           |                                            |
|----|-----------|--------------------------------------------|
| in | <i>sd</i> | Reference to <a href="#">Side</a> instance |
| in | <i>a</i>  | Value to prescribe                         |

**void setBC ( int code, real\_t a )**

Prescribe a constant boundary condition for a given code.

Parameters

|    |             |                                 |
|----|-------------|---------------------------------|
| in | <i>code</i> | Code for which value is imposed |
| in | <i>a</i>    | Value to prescribe              |

**void setBC ( real\_t u )**

Prescribe a constant boundary condition on all boundary sides.

Parameters

|    |          |                    |
|----|----------|--------------------|
| in | <i>u</i> | Value to prescribe |
|----|----------|--------------------|

**void setBC ( const Side & sd, const LocalVect< real\_t, 4 > & u )**

Prescribe a constant boundary condition at a given side.

Parameters

|    |           |                                                                                                                                              |
|----|-----------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i> | Reference to <a href="#">Side</a> instance                                                                                                   |
| in | <i>u</i>  | Vector (instance of class <a href="#">LocalVect</a> ) with as components the constant values to prescribe for the four fields (r, vx, vy, p) |

**void setBC ( int *code*, const LocalVect< real.t, 4 > & *u* )**

Prescribe a constant boundary condition for a given code.

Parameters

|    |             |                                                                                                                                              |
|----|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>code</i> | Code for which value is imposed                                                                                                              |
| in | <i>u</i>    | Vector (instance of class <a href="#">LocalVect</a> ) with as components the constant values to prescribe for the four fields (r, vx, vy, p) |

**void setBC ( const LocalVect< real.t, 4 > & *u* )**

Prescribe a constant boundary condition at all boundary sides.

Parameters

|    |          |                                                                                                                                              |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>u</i> | Vector (instance of class <a href="#">LocalVect</a> ) with as components the constant values to prescribe for the four fields (r, vx, vy, p) |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------|

**real.t getR ( size.t *i* ) const**

Return density at given element label.

Parameters

|    |          |                               |
|----|----------|-------------------------------|
| in | <i>i</i> | <a href="#">Element</a> label |
|----|----------|-------------------------------|

**real.t getV ( size.t *i*, size.t *j* ) const**

Return velocity at given element label

Parameters

|    |          |                               |
|----|----------|-------------------------------|
| in | <i>i</i> | <a href="#">Element</a> label |
| in | <i>j</i> | component index (1 or 2)      |

**real.t getP ( size.t *i* ) const**

Return pressure at given element label.

Parameters

|    |          |                               |
|----|----------|-------------------------------|
| in | <i>i</i> | <a href="#">Element</a> label |
|----|----------|-------------------------------|

**bool setReconstruction ( const Vect< real.t > & *U*, Vect< real.t > & *LU*, Vect< real.t > & *RU*, size.t *dof* )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void Initialize ( )** [protected], [inherited]

Construction of normals to sides.

Convention: for a given side, getPtrElement(1) is the left element and getPtrElement(2) is the right element. The normal goes from left to right. For boundary sides, the normal points outward.

**void setTimeStep ( real.t  $dt$  )** [inherited]

Assign time step value.

Parameters

|    |      |                 |
|----|------|-----------------|
| in | $dt$ | Time step value |
|----|------|-----------------|

**void setCFL ( real.t  $CFL$  )** [inherited]

Assign CFL value.

Parameters

|    |       |              |
|----|-------|--------------|
| in | $CFL$ | Value of CFL |
|----|-------|--------------|

**void setReferenceLength ( real.t  $dx$  )** [inherited]

Assign reference length value.

Parameters

|    |      |                           |
|----|------|---------------------------|
| in | $dx$ | Value of reference length |
|----|------|---------------------------|

**void setVerbose ( int  $v$  )** [inherited]

Set verbosity parameter.

Parameters

|    |     |                              |
|----|-----|------------------------------|
| in | $v$ | Value of verbosity parameter |
|----|-----|------------------------------|

**void setMethod ( const Method &  $s$  )** [inherited]

Choose a flux solver.

Parameters

|    |     |                  |
|----|-----|------------------|
| in | $s$ | Solver to choose |
|----|-----|------------------|

**void setLimiter ( Limiter  $l$  )** [inherited]

Choose a flux limiter.

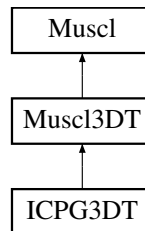
Parameters

|    |          |                   |
|----|----------|-------------------|
| in | <i>l</i> | Limiter to choose |
|----|----------|-------------------|

## 7.47 ICPG3DT Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D.

Inheritance diagram for ICPG3DT:



### Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum `SolverType` {  
`ROE_SOLVER` = 0,  
`VFROE_SOLVER` = 1,  
`LF_SOLVER` = 2,  
`RUSANOV_SOLVER` = 3,  
`HLL_SOLVER` = 4,  
`HLLC_SOLVER` = 5,  
`MAX_SOLVER` = 6 }

*Enumeration of various solvers for the Riemann problem.*

### Public Member Functions

- `ICPG3DT (Mesh &ms)`  
*Constructor using mesh data.*
- `ICPG3DT (Mesh &ms, Vect< real.t > &r, Vect< real.t > &v, Vect< real.t > &p)`  
*Constructor using mesh and initial data.*
- `~ICPG3DT ()`  
*Destructor.*
- `void setReconstruction ()`

- Reconstruct.*
- `real.t runOneTimeStep ()`  
*Advance one time step.*
- `void Forward (const Vect< real.t > &flux, Vect< real.t > &field)`  
*Add flux to field.*
- `real.t getFlux ()`  
*Return flux.*
- `void setReferenceLength (real.t dx)`  
*Assign a reference length.*
- `void setTimeStep (real.t dt)`  
*Assign a time step.*
- `void setCFL (real.t CFL)`  
*Assign CFL value.*
- `real.t getReferenceLength () const`  
*Return reference length.*
- `real.t getTimeStep () const`  
*Return time step.*
- `real.t getCFL () const`  
*Return CFL.*
- `void setGamma (real.t gamma)`  
*Set  $\gamma$  value.*
- `void setCv (real.t Cv)`  
*Set value of  $C_v$  (Heat capacity at constant volume)*
- `void setCp (real.t Cp)`  
*Set value of  $C_p$  (Heat capacity at constant pressure)*
- `void setKappa (real.t Kappa)`  
*Set Kappa value.*
- `real.t getGamma () const`  
*Return value of  $\gamma$ .*
- `real.t getCv () const`  
*Return value of  $C_v$  (Heat capacity at constant volume)*
- `real.t getCp () const`  
*Return value of  $C_p$  (Heat capacity at constant pressure)*
- `real.t getKappa () const`  
*Return value of  $\kappa$ .*
- `Mesh & getMesh ()`  
*Return reference to mesh instance.*
- `Mesh * getPtrMesh ()`  
*Return pointer to mesh.*
- `void getMomentum (Vect< real.t > &m) const`  
*Calculate elementwise momentum.*
- `void getInternalEnergy (Vect< real.t > &e) const`  
*Calculate elementwise internal energy.*
- `void getTotalEnergy (Vect< real.t > &e) const`  
*Return elementwise total energy.*
- `void getSoundSpeed (Vect< real.t > &s) const`

- Return elementwise sound speed.*

  - `void getMach (Vect< real.t > &m) const`
- Return elementwise Mach number.*

  - `bool setReconstruction (const Vect< real.t > &U, Vect< real.t > &LU, Vect< real.t > &RU, size_t dof)`
- Function to reconstruct by the *Muscl* method.*

  - `real.t getMinimumFaceArea () const`
- Return minimum area of faces in the mesh.*

  - `real.t getMinimumElementVolume () const`
- Return minimum volume of elements in the mesh.*

  - `real.t getMaximumFaceArea () const`
- Return maximum area of faces in the mesh.*

  - `real.t getMaximumElementVolume () const`
- Return maximum volume of elements in the mesh.*

  - `real.t getMeanFaceArea () const`
- Return mean area of faces in the mesh.*

  - `real.t getMeanElementVolume () const`
- Return mean volume of elements in the mesh.*

  - `real.t getMinimumEdgeLength () const`
- Return minimum length of edges in the mesh.*

  - `real.t getMinimumVolumebyArea () const`
- Return minimum volume by area in the mesh.*

  - `real.t getMaximumEdgeLength () const`
- Return maximum length of edges in the mesh.*

  - `real.t getTauLim () const`
- Return value of tau lim.*

  - `real.t getComega () const`
- Return value of Comega.*

  - `void setbetalim (real.t bl)`
- Assign value of beta lim.*

  - `Mesh & getMesh () const`
- Return reference to *Mesh* instance.*

  - `void setVerbose (int v)`
- Set verbosity parameter.*

  - `void setMethod (const Method &s)`
- Choose a flux solver.*

  - `void setSolidZoneCode (int c)`
- Choose a code for solid zone.*

  - `bool getSolidZone () const`
- Return flag for presence of solid zones.*

  - `int getSolidZoneCode () const`
- Return code of solid zone, 0 if this one is not present.*

  - `void setLimiter (Limiter l)`
- Choose a flux limiter.*



### 7.47.1 Detailed Description

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D.  
Solution method is a second-order MUSCL Finite Volume scheme with tetrahedra

### 7.47.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

*FIRST\_ORDER\_METHOD* First Order upwind method

*MULTI\_SLOPE\_Q\_METHOD* Multislope Q method

*MULTI\_SLOPE\_M\_METHOD* Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

*MINMOD\_LIMITER* MinMod limiter

*VANLEER\_LIMITER* Van Leer limiter

*SUPERBEE\_LIMITER* Superbee limiter

*VANALBADA\_LIMITER* Van Albada limiter

*MAX\_LIMITER* Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

*ROE\_SOLVER* Roe solver

*VROE\_SOLVER* Finite Volume Roe solver

*LF\_SOLVER* LF solver

*RUSANOV\_SOLVER* Rusanov solver

*HLL\_SOLVER* HLL solver

*HLLC\_SOLVER* HLLC solver

*MAX\_SOLVER* Max solver

### 7.47.3 Constructor & Destructor Documentation

**ICPG3DT ( Mesh & *ms* )**

Constructor using mesh data.

Parameters

|    |           |                               |
|----|-----------|-------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance |
|----|-----------|-------------------------------|

**ICPG3DT ( [Mesh](#) & *ms*, Vect< real\_t > & *r*, Vect< real\_t > & *v*, Vect< real\_t > & *p* )**

Constructor using mesh and initial data.

Parameters

|    |           |                                                                                    |
|----|-----------|------------------------------------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance                                                      |
| in | <i>r</i>  | Elementwise initial density vector (as instance of <a href="#">Element Vect</a> )  |
| in | <i>v</i>  | Elementwise initial velocity vector (as instance of <a href="#">Element Vect</a> ) |
| in | <i>p</i>  | Elementwise initial pressure vector (as instance of <a href="#">Element Vect</a> ) |

### 7.47.4 Member Function Documentation

**void setReconstruction ( )**

Reconstruct.

exit(3) if reconstruction failed

**bool setReconstruction ( const Vect< real\_t > & *U*, Vect< real\_t > & *LU*, Vect< real\_t > & *RU*, size\_t *dof* )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |            |                             |
|-----|------------|-----------------------------|
| in  | <i>U</i>   | Field to reconstruct        |
| out | <i>LU</i>  | Left gradient vector        |
| out | <i>RU</i>  | Right gradient vector       |
| in  | <i>dof</i> | Label of dof to reconstruct |

**void setVerbose ( int *v* )** [inherited]

Set verbosity parameter.

Parameters

|    |          |                              |
|----|----------|------------------------------|
| in | <i>v</i> | Value of verbosity parameter |
|----|----------|------------------------------|

**void setMethod ( const Method & *s* )** [inherited]

Choose a flux solver.

Parameters

|    |          |                  |
|----|----------|------------------|
| in | <i>s</i> | Solver to choose |
|----|----------|------------------|

**void setLimiter ( Limiter *l* )** [inherited]

Choose a flux limiter.

Parameters

|    |   |                   |
|----|---|-------------------|
| in | l | Limiter to choose |
|----|---|-------------------|

## 7.48 IOField Class Reference

Enables working with files in the XML Format.

Inherits XMLParser.

### Public Types

- enum [AccessType](#)  
*Enumerated values for file access type.*

### Public Member Functions

- [IOField](#) ()  
*Default constructor.*
- [IOField](#) (const string &file, [AccessType](#) access, bool compact=true)  
*Constructor using file name.*
- [IOField](#) (const string &mesh\_file, const string &file, [Mesh](#) &ms, [AccessType](#) access, bool compact=true)  
*Constructor using file name, mesh file and mesh.*
- [IOField](#) (const string &file, [Mesh](#) &ms, [AccessType](#) access, bool compact=true)  
*Constructor using file name and mesh.*
- [~IOField](#) ()  
*Destructor.*
- void [setMeshFile](#) (const string &file)  
*Set mesh file.*
- void [open](#) ()  
*Open file.*
- void [open](#) (const string &file, [AccessType](#) access)  
*Open file.*
- void [close](#) ()  
*Close file.*
- void [put](#) ([Mesh](#) &ms)  
*Store mesh in file.*
- void [put](#) (const [Vect](#)< [real\\_t](#) > &v)  
*Store Vect instance v in file.*
- void [put](#) (const [PETScVect](#)< [real\\_t](#) > &v)  
*Store PETScVect instance v in file.*
- [real\\_t](#) [get](#) ([Vect](#)< [real\\_t](#) > &v)  
*Get Vect v instance from file.*
- int [get](#) ([Vect](#)< [real\\_t](#) > &v, [real\\_t](#) t)  
*Get Vect v instance from file corresponding to a specific time value.*
- void [saveGMSH](#) (string output\_file, string mesh\_file)  
*Save field vectors in a file using GMSH format.*

### 7.48.1 Detailed Description

Enables working with files in the XML Format.

This class has methods to store vectors in files and read from files.

### 7.48.2 Constructor & Destructor Documentation

**IOField ( const string & *file*, AccessType *access*, bool *compact* = true )**

Constructor using file name.

Parameters

|    |                |                                                                                                                                                                                           |
|----|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>file</i>    | File name.                                                                                                                                                                                |
| in | <i>access</i>  | Access code. This number is to be chosen among two enumerated values: <ul style="list-style-type: none"> <li>IOField::IN to read the file</li> <li>IOField::OUT to write on it</li> </ul> |
| in | <i>compact</i> | Flag to choose a compact storage or not [Default: true]                                                                                                                                   |

**IOField ( const string & *mesh\_file*, const string & *file*, Mesh & *ms*, AccessType *access*, bool *compact* = true )**

Constructor using file name, mesh file and mesh.

Parameters

|    |                  |                                                                                                                                                                                           |
|----|------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh_file</i> | File containing mesh                                                                                                                                                                      |
| in | <i>file</i>      | File that contains field stored or to store                                                                                                                                               |
| in | <i>ms</i>        | <a href="#">Mesh</a> instance                                                                                                                                                             |
| in | <i>access</i>    | Access code. This number is to be chosen among two enumerated values: <ul style="list-style-type: none"> <li>IOField::IN to read the file</li> <li>IOField::OUT to write on it</li> </ul> |
| in | <i>compact</i>   | Flag to choose a compact storage or not [Default: true]                                                                                                                                   |

**IOField ( const string & *file*, Mesh & *ms*, AccessType *access*, bool *compact* = true )**

Constructor using file name and mesh.

Parameters

|    |                |                                                                                                                                                                                           |
|----|----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>file</i>    | File that contains field stored or to store                                                                                                                                               |
| in | <i>ms</i>      | <a href="#">Mesh</a> instance                                                                                                                                                             |
| in | <i>access</i>  | Access code. This number is to be chosen among two enumerated values: <ul style="list-style-type: none"> <li>IOField::IN to read the file</li> <li>IOField::OUT to write on it</li> </ul> |
| in | <i>compact</i> | Flag to choose a compact storage or not [Default: true]                                                                                                                                   |

### 7.48.3 Member Function Documentation

**void setMeshFile ( const string & *file* )**

Set mesh file.

Parameters

|           |             |                           |
|-----------|-------------|---------------------------|
| <b>in</b> | <i>file</i> | <a href="#">Mesh</a> file |
|-----------|-------------|---------------------------|

**void open ( )**

Open file.

Case where file name has been previously given (in the constructor).

**void open ( const string &file, AccessType access )**

Open file.

Parameters

|           |               |                                                                                                                                                                                               |
|-----------|---------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>file</i>   | File name.                                                                                                                                                                                    |
| <b>in</b> | <i>access</i> | Access code. This number is to be chosen among two enumerated values: <ul style="list-style-type: none"> <li>• IOField::IN to read the file</li> <li>• IOField::OUT to write on it</li> </ul> |

**void put ( const Vect< real.t > &v )**

Store [Vect](#) instance v in file.

Parameters

|           |          |                                        |
|-----------|----------|----------------------------------------|
| <b>in</b> | <i>v</i> | <a href="#">Vect</a> instance to store |
|-----------|----------|----------------------------------------|

**void put ( const PETScVect< real.t > &v )**

Store [PETScVect](#) instance v in file.

Parameters

|           |          |                                             |
|-----------|----------|---------------------------------------------|
| <b>in</b> | <i>v</i> | <a href="#">PETScVect</a> instance to store |
|-----------|----------|---------------------------------------------|

**real.t get ( Vect< real.t > &v )**

Get [Vect](#) v instance from file.

First time step is read from the XML file.

**int get ( Vect< real.t > &v, real.t t )**

Get [Vect](#) v instance from file corresponding to a specific time value.

The sought vector corresponding to the time value is read from the XML file.

Parameters

|               |          |                 |
|---------------|----------|-----------------|
| <b>in,out</b> | <i>v</i> | Vector instance |
| <b>in</b>     | <i>t</i> | Time value      |

**void saveGMSH ( string *output\_file*, string *mesh\_file* )**

Save field vectors in a file using **GMSH** format.

This member function enables avoiding the use of `cfield`. It must be used once all field vectors have been stored in output file. It closes this file and copies its contents to a **GMSH** file.

Parameters

|                 |                          |                                                          |
|-----------------|--------------------------|----------------------------------------------------------|
| <code>in</code> | <code>output_file</code> | Output file name where to store using <b>GMSH</b> format |
| <code>in</code> | <code>mesh_file</code>   | File containing mesh data                                |

## 7.49 IPF Class Reference

To read project parameters from a file in **IPF** format.

### Public Member Functions

- **IPF** ()  
*Default constructor.*
- **IPF** (const string &file)  
*Constructor that gives the data file name.*
- **IPF** (const string &prog, const string &file)  
*Constructor that reads parameters in file *file* and prints header information for the calling program *prog*. It reads parameters in **IPF** Format from this file.*
- **~IPF** ()  
*Destructor.*
- **real.t** **getDisplay** ()  
*Display acquired parameters.*
- **int** **getVerbose** () const  
*Return parameter read using keyword **Verbose**.*
- **int** **getOutput** () const  
*Return parameter read using keyword **Output**.*
- **int** **getSave** () const  
*Return parameter read using keyword **Save**.*
- **int** **getPlot** () const  
*Return parameter read using keyword **Plot**.*
- **int** **getBC** () const  
*Return parameter read using keyword **BC**.*
- **int** **getBF** () const  
*Return parameter read using keyword **BF**.*
- **int** **getSF** () const  
*Return parameter read using keyword **SF**.*
- **int** **getInit** () const  
*Return parameter read using keyword **Init**.*
- **int** **getData** () const  
*Return parameter read using keyword **Data**.*
- **size.t** **getNbSteps** () const  
*Return parameter read using keyword **NbSteps**.*
- **size.t** **getNbIter** () const

- Return parameter read using keyword **NbIter**.*

  - `real.t getTimeStep ()` const
- Return parameter read using keyword **TimeStep**.*

  - `real.t getMaxTime ()` const
- Return parameter read using keyword **MaxTime**.*

  - `real.t getTolerance ()` const
- Return parameter read using keyword **Tolerance**.*

  - `int getIntPar (size_t n=1)` const
- Return *n*-th parameter read using keyword **IntPar***

  - `string getStringPar (size_t n=1)` const
- Return *n*-th parameter read using keyword **StringPar**.*

  - `real.t getDoublePar (size_t n=1)` const
- Return *n*-th parameter read using keyword **DoublePar**.*

  - `Point< real.t > getPointDoublePar (size_t n=1)` const
- Return *n*-th parameter read using keyword **PointDoublePar**.*

  - `complex.t getComplexPar (size_t n=1)` const
- Return *n*-th parameter read using keyword **StringPar**.*

  - `string getString (const string &label)` const
- Return parameter corresponding to a given label, when its value is a string.*

  - `string getString (const string &label, string def)` const
- Return parameter corresponding to a given label, when its value is a string.*

  - `int getInteger (const string &label)` const
- Return parameter corresponding to a given label, when its value is an integer.*

  - `int getInteger (const string &label, int def)` const
- Return parameter corresponding to a given label, when its value is an integer.*

  - `real.t getDouble (const string &label)` const
- Return parameter corresponding to a given label, when its value is a real.t.*

  - `real.t getDouble (const string &label, real.t def)` const
- Return parameter corresponding to a given label, when its value is a real.t.*

  - `complex.t getComplex (const string &label)` const
- Return parameter corresponding to a given label, when its value is a complex number.*

  - `complex.t getComplex (const string &label, complex.t def)` const
- Return parameter corresponding to a given label, when its value is a complex number.*

  - `int contains (const string &label)` const
- check if the project file contains a given parameter*

  - `void get (const string &label, Vect< real.t > &a)` const
- Read an array of real values, corresponding to a given label.*

  - `real.t getArraySize (const string &label, size_t j)` const
- Return an array entry for a given label.*

  - `void get (const string &label, int &a)` const
- Return integer parameter corresponding to a given label.*

  - `void get (const string &label, real.t &a)` const
- Return real parameter corresponding to a given label.*

  - `void get (const string &label, complex.t &a)` const
- Return complex parameter corresponding to a given label.*

  - `void get (const string &label, string &a)` const



- Return string parameter corresponding to a given label.*

  - string `getProject ()` const  
*Return parameter read using keyword **Project**.*
  - string `getDomainFile ()` const  
*Return parameter using keyword **Mesh**.*
  - string `getMeshFile (size_t i=1)` const  
*Return *i*-th parameter read using keyword **mesh\_file**.*
  - string `getInitFile ()` const  
*Return parameter read using keyword **InitFile**.*
  - string `getRestartFile ()` const  
*Return parameter read using keyword **RestartFile**.*
  - string `getBCFile ()` const  
*Return parameter read using keyword **BCFile**.*
  - string `getBFFile ()` const  
*Return parameter read using keyword **BFFile**.*
  - string `getSFFile ()` const  
*Return parameter read using keyword **SFFile**.*
  - string `getSaveFile ()` const  
*Return parameter read using keyword **SaveFile**.*
  - string `getPlotFile (int i=1)` const  
*Return *i*-th parameter read using keyword **PlotFile**.*
  - string `getPrescriptionFile (int i=1)` const  
*Return parameter read using keyword **DataFile**.*
  - string `getAuxFile (size_t i=1)` const  
*Return *i*-th parameter read using keyword **Auxfile**.*
  - string `getDensity ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for density function.*
  - string `getElectricConductivity ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for electric conductivity.*
  - string `getElectricPermittivity ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for electric permittivity.*
  - string `getMagneticPermeability ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for magnetic permeability.*
  - string `getPoissonRatio ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for Poisson ratio.*
  - string `getThermalConductivity ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for thermal conductivity.*
  - string `getRhoCp ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for density \* specific heat.*
  - string `getViscosity ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for viscosity.*
  - string `getYoungModulus ()` const  
*Return expression (to be parsed, function of *x*, *y*, *z*, *t*) for Young's modulus.*

### 7.49.1 Detailed Description

To read project parameters from a file in [IPF](#) format.

This class can be used to acquire various parameters from a parameter file of [IPF](#) (Input Project File). The declaration of an instance of this class avoids reading data in your main program. The acquired parameters are retrieved through information members of the class. Note that all the parameters have default values

### 7.49.2 Constructor & Destructor Documentation

**IPF ( const string &file )**

Constructor that gives the data file name.

It reads parameters in [IPF](#) Format from this file.

### 7.49.3 Member Function Documentation

**int getOutput ( ) const**

Return parameter read using keyword **Output**.

This parameter can be used to control output behavior in a program.

**int getSave ( ) const**

Return parameter read using keyword **Save**.

This parameter can be used to control result saving in a program (*e.g.* for a restarting purpose).

**int getPlot ( ) const**

Return parameter read using keyword **Plot**.

This parameter can be used to control result saving for plotting in a program.

**int getBC ( ) const**

Return parameter read using keyword **BC**.

This parameter can be used to set a boundary condition flag.

**int getBF ( ) const**

Return parameter read using keyword **BF**.

This parameter can be used to set a body force flag.

**int getSF ( ) const**

Return parameter read using keyword **SF**.

This parameter can be used to set a surface force flag.

**int getInit ( ) const**

Return parameter read using keyword **Init**.

This parameter can be used to set an initial data flag.

**int getData ( ) const**

Return parameter read using keyword **Data**.

This parameter can be used to set a various data flag.

**size\_t getNbSteps ( ) const**

Return parameter read using keyword **NbSteps**.

This parameter can be used to read a number of time steps.

**size\_t getNbIter ( ) const**

Return parameter read using keyword **NbIter**.

This parameter can be used to read a number of iterations.

**real\_t getTimeStep ( ) const**

Return parameter read using keyword **TimeStep**.

This parameter can be used to read a time step value.

**real\_t getMaxTime ( ) const**

Return parameter read using keyword **MaxTime**.

This parameter can be used to read a maximum time value.

**real\_t getTolerance ( ) const**

Return parameter read using keyword **Tolerance**.

This parameter can be used to read a tolerance value to control convergence.

**int getIntPar ( size\_t n = 1 ) const**

Return n-th parameter read using keyword **IntPar**

Here we have at most 20 integer extra parameters that can be used for any purpose. Default value for n is 1

**string getStringPar ( size\_t n = 1 ) const**

Return n-th parameter read using keyword **StringPar**.

Here we have at most 20 integer extra parameters that can be used for any purpose. Default value for n is 1

**real\_t getDoublePar ( size\_t n = 1 ) const**

Return n-th parameter read using keyword **DoublePar**.

Here we have at most 20 integer extra parameters that can be used for any purpose. Default value for n is 1

**Point<real\_t> getPointDoublePar ( size\_t n = 1 ) const**

Return n-th parameter read using keyword **PointDoublePar**.

Here we have at most 20 integer extra parameters that can be used for any purpose. Default value for n is 1

**complex.t getComplexPar ( size.t *n* = 1 ) const**

Return *n*-th parameter read using keyword **StringPar**.

Here we have at most 20 integer extra parameters that can be used for any purpose. Default value for *n* is 1

**string getString ( const string & *label* ) const**

Return parameter corresponding to a given label, when its value is a string.

Parameters

|           |              |                                                                                                                                    |
|-----------|--------------|------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>label</i> | Label that identifies the string (read from input file) If this label is not found an error message is displayed and program stops |
|-----------|--------------|------------------------------------------------------------------------------------------------------------------------------------|

**string getString ( const string & *label*, string *def* ) const**

Return parameter corresponding to a given label, when its value is a string.

Case where a default value is provided

Parameters

|           |              |                                                                     |
|-----------|--------------|---------------------------------------------------------------------|
| <i>in</i> | <i>label</i> | Label that identifies the string (read from input file)             |
| <i>in</i> | <i>def</i>   | Default value: Value to assign if the sought parameter is not found |

**int getInteger ( const string & *label* ) const**

Return parameter corresponding to a given label, when its value is an integer.

Parameters

|           |              |                                                                                                                                            |
|-----------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>label</i> | Label that identifies the integer number (read from input file) If this label is not found an error message is displayed and program stops |
|-----------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|

**int getInteger ( const string & *label*, int *def* ) const**

Return parameter corresponding to a given label, when its value is an integer.

Case where a default value is provided

Parameters

|           |              |                                                                     |
|-----------|--------------|---------------------------------------------------------------------|
| <i>in</i> | <i>label</i> | Label that identifies the integer number (read from input file).    |
| <i>in</i> | <i>def</i>   | Default value: Value to assign if the sought parameter is not found |

**real.t getDouble ( const string & *label* ) const**

Return parameter corresponding to a given label, when its value is a real.t.

Parameters

|           |              |                                                                                                                                           |
|-----------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>label</i> | Label that identifies the real number (read from input file). If this label is not found an error message is displayed and program stops. |
|-----------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------|

**`real_t getDouble ( const string & label, real_t def ) const`**

Return parameter corresponding to a given label, when its value is a real\_t.

Case where a default value is provided

Parameters

|           |              |                                                                     |
|-----------|--------------|---------------------------------------------------------------------|
| <b>in</b> | <i>label</i> | Label that identifies the real number (read from input file)        |
| <b>in</b> | <i>def</i>   | Default value: Value to assign if the sought parameter is not found |

**complex\_t getComplex ( const string & label ) const**

Return parameter corresponding to a given label, when its value is a complex number.

Parameters

|           |              |                                                                                                                                            |
|-----------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>label</i> | Label that identifies the complex number (read from input file) If this label is not found an error message is displayed and program stops |
|-----------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------|

**complex\_t getComplex ( const string & label, complex\_t def ) const**

Return parameter corresponding to a given label, when its value is a complex number.

Case where a default value is provided

Parameters

|           |              |                                                                     |
|-----------|--------------|---------------------------------------------------------------------|
| <b>in</b> | <i>label</i> | Label that identifies the complex number (read from input file)     |
| <b>in</b> | <i>def</i>   | Default value: Value to assign if the sought parameter is not found |

**int contains ( const string & label ) const**

check if the project file contains a given parameter

Parameters

|           |              |                                                 |
|-----------|--------------|-------------------------------------------------|
| <b>in</b> | <i>label</i> | Label that identifies the label to seek in file |
|-----------|--------------|-------------------------------------------------|

Returns

0 if the parameter is not found, n if the parameter is found, where n is the parameter index in the parameter list

**void get ( const string & label, Vect< real\_t > & a ) const**

Read an array of real values, corresponding to a given label.

Parameters

|           |              |                                                                               |
|-----------|--------------|-------------------------------------------------------------------------------|
| <b>in</b> | <i>label</i> | Label that identifies the array (read from input file).                       |
| <b>in</b> | <i>a</i>     | Vector that contain the array. The vector is properly resized before filling. |

Remarks

If this label is not found an error message is displayed.

**real\_t getArraySize ( const string & label, size\_t j ) const**

Return an array entry for a given label.

## Parameters

|    |              |                                                         |
|----|--------------|---------------------------------------------------------|
| in | <i>label</i> | Label that identifies the array (read from input file). |
| in | <i>j</i>     | Index of entry in the array (Starting from 1)           |

## Remarks

If this label is not found an error message is displayed and program stops.

**void get ( const string & *label*, int & *a* ) const**

Return integer parameter corresponding to a given label.

## Parameters

|     |              |                                                                                                                                                          |
|-----|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| in  | <i>label</i> | Label that identifies the integer number (read from input file).                                                                                         |
| out | <i>a</i>     | Returned value. If this label is not found an error message is displayed and program stops. Note: This member function can be used instead of getInteger |

**void get ( const string & *label*, real.t & *a* ) const**

Return real parameter corresponding to a given label.

## Parameters

|     |              |                                                                                                                                                         |
|-----|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|
| in  | <i>label</i> | Label that identifies the real (real.t) number (read from input file).                                                                                  |
| out | <i>a</i>     | Returned value. If this label is not found an error message is displayed and program stops. Note: This member function can be used instead of getReal.T |

**void get ( const string & *label*, complex.t & *a* ) const**

Return complex parameter corresponding to a given label.

## Parameters

|     |              |                                                                                             |
|-----|--------------|---------------------------------------------------------------------------------------------|
| in  | <i>label</i> | Label that identifies the complex number (read from input file).                            |
| out | <i>a</i>     | Returned value. If this label is not found an error message is displayed and program stops. |

**void get ( const string & *label*, string & *a* ) const**

Return string parameter corresponding to a given label.

## Parameters

|     |              |                                                                                                                                                                                                                     |
|-----|--------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in  | <i>label</i> | Label that identifies the atring (read from input file).                                                                                                                                                            |
| out | <i>a</i>     | Returned value. Note: This member function can be used instead of getString If this label is not found an error message is displayed and program stops. Note: This member function can be used instead of getString |

**string getProject ( ) const**

Return parameter read using keyword **Project**.

This parameter can be used to read a project's name.

**string getMeshFile ( size\_t i = 1 ) const**

Return i-th parameter read using keyword **mesh\_file**.

Here we have at most 10 integer extra parameters that can be used for any purpose. Default value for i is 1

**string getInitFile ( ) const**

Return parameter read using keyword **InitFile**.

This parameter can be used to read an initial data file name.

**string getRestartFile ( ) const**

Return parameter read using keyword **RestartFile**.

This parameter can be used to read a restart file name.

**string getBCFile ( ) const**

Return parameter read using keyword **BCFile**.

This parameter can be used to read a boundary condition file name.

**string getBFFile ( ) const**

Return parameter read using keyword **BFFile**.

This parameter can be used to read a body force file name.

**string getSFFile ( ) const**

Return parameter read using keyword **SFFile**.

This parameter can be used to read a source force file name.

**string getSaveFile ( ) const**

Return parameter read using keyword **SaveFile**.

This parameter can be used to read a save file name.

**string getPlotFile ( int i = 1 ) const**

Return i-th parameter read using keyword **PlotFile**.

Here we have at most 10 integer extra parameters that can be used for plot file names. Default value for i is 1

**string getPrescriptionFile ( int i = 1 ) const**

Return parameter read using keyword **DataFile**.

This parameter can be used to read a [Prescription](#) file.

**string getAuxFile ( size\_t i = 1 ) const**

Return i-th parameter read using keyword **Auxfile**.

Here we have at most 10 integer extra parameters that can be used for any auxiliary file names. Default value for i is 1



## 7.50 Iter< T\_ > Class Template Reference

Class to drive an iterative process.

### Public Member Functions

- [Iter](#) ()  
*Default Constructor.*
- [Iter](#) (int max\_it, [real\\_t](#) toler, int verbose=0)  
*Constructor with iteration parameters.*
- [~Iter](#) ()  
*Destructor.*
- void [setMaxIter](#) (int max\_it)  
*Set maximal number of iterations.*
- void [setTolerance](#) ([real\\_t](#) toler)  
*Set tolerance value for convergence.*
- void [setVerbose](#) (int v)  
*Set verbosity parameter.*
- bool [check](#) ([Vect](#)< T\_ > &u, const [Vect](#)< T\_ > &v, int opt=2)  
*Check convergence.*

### 7.50.1 Detailed Description

**template<class T\_>class OFELI::Iter< T\_ >**

Class to drive an iterative process.

This template class enables monitoring any iterative process. It simply sets default values for tolerance, maximal number of iterations and enables checking convergence using two successive iterates.

### 7.50.2 Constructor & Destructor Documentation

**Iter ( )**

Default Constructor.

This constructor set default values: the maximal number of iterations is set to 100 and the tolerance to 1.e-8

**Iter ( int max\_it, real\_t toler, int verbose = 0 )**

Constructor with iteration parameters.

Parameters

|    |                |                                                                                                     |
|----|----------------|-----------------------------------------------------------------------------------------------------|
| in | <i>max_it</i>  | Maximum number of iterations                                                                        |
| in | <i>toler</i>   | Tolerance value for convergence                                                                     |
| in | <i>verbose</i> | Verbosity parameter [default: 0] 0: No message output, > 0: message output with increasing display. |

### 7.50.3 Member Function Documentation

**bool check ( Vect< T\_ > &u, const Vect< T\_ > &v, int opt = 2 )**

Check convergence.

Parameters

|        |       |                                                                                      |
|--------|-------|--------------------------------------------------------------------------------------|
| in,out | $u$   | Solution vector at previous iteration                                                |
| in     | $v$   | Solution vector at current iteration                                                 |
| in     | $opt$ | Vector norm for convergence checking 1: 1-norm, 2: 2-norm, 0: Max. norm [default: 2] |

Returns

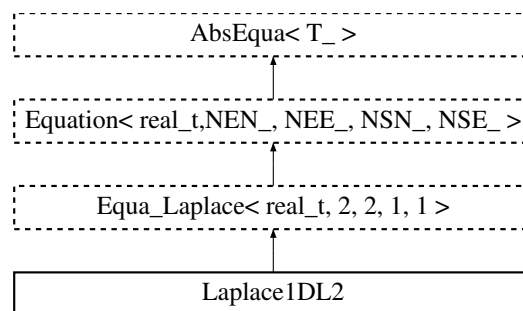
true if convergence criterion is satisfied, false if not

After checking, this function copied  $v$  into  $u$ .

## 7.51 Laplace1DL2 Class Reference

To build element equation for a 1-D elliptic equation using the 2-Node line element ( $P_1$ ).

Inheritance diagram for Laplace1DL2:



### Public Member Functions

- [Laplace1DL2](#) ([Element](#) \*el)  
*Constructor for an element.*
- [Laplace1DL2](#) ([Mesh](#) &ms, [Vect](#)< [real\\_t](#) > &u)
- [~Laplace1DL2](#) ()  
*Destructor.*
- void [Matrix](#) ([real\\_t](#) coef=1.)  
*Add finite element matrix to left hand side.*
- void [BodyRHS](#) (const [Vect](#)< [real\\_t](#) > &f)  
*Add Right-Hand Side Contribution.*
- void [BoundaryRHS](#) (int n, [real\\_t](#) p)  
*Add Neumann contribution to Right-Hand Side.*
- void [setBoundaryCondition](#) ([real\\_t](#) f, int lr)  
*Set Dirichlet boundary data.*
- void [setTraction](#) ([real\\_t](#) f, int lr)  
*Set Traction data.*
- int [run](#) ()
- virtual void [build](#) ()  
*Solve the equation.*
- void [build](#) ([EigenProblemSolver](#) &e)

- *Build the linear system for an eigenvalue problem.*
- virtual void **buildEigen** (int opt=0)
- *Build matrices for an eigenvalue problem.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)
- *Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)
- *Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)
- *Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)
- *Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)
- *Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)
- *Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)
- *Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)
- *Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)
- *Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)
- *Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()
- *Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()
- *Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)
- *Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)
- *Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)
- *Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)

- Assemble side matrix into global one.*
  - void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble side right-hand side vector into global one.*
  - void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*
  - size\_t [getNbNodes](#) () const
- Return number of element nodes.*
  - size\_t [getNbEq](#) () const
- Return number of element equations.*
  - void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*
  - [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*
  - void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*
  - [Mesh](#) & [getMesh](#) () const
- Return reference to [Mesh](#) instance.*
  - [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
  - void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)
- Choose solver for the linear system.*
  - int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > **eMat**  
*LocalMatrix* instance containing local matrix associated to current element.
- **LocalMatrix**< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > **sMat**  
*LocalMatrix* instance containing local matrix associated to current side.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **ePrev**  
*LocalVect* instance containing local vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRHS**  
*LocalVect* instance containing local right-hand side vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRes**  
*LocalVect* instance containing local residual vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NSE<sub>-</sub> > **sRHS**  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void **Init** (const **Element** \*el)  
Set element arrays to zero.
- void **Init** (const **Side** \*sd)  
Set side arrays to zero.

### 7.51.1 Detailed Description

To build element equation for a 1-D elliptic equation using the 2-Node line element (P<sub>1</sub> ).

### 7.51.2 Constructor & Destructor Documentation

**Laplace1DL2** ( **Mesh** & *ms*, **Vect**< **real.t** > & *u* )

Constructor using mesh instance and solution vector

Parameters

|               |           |                                                                                  |
|---------------|-----------|----------------------------------------------------------------------------------|
| <b>in</b>     | <i>ms</i> | <b>Mesh</b> instance                                                             |
| <b>in,out</b> | <i>u</i>  | <b>Vect</b> instance that contains, after execution of <b>run()</b> the solution |

### 7.51.3 Member Function Documentation

**void Matrix** ( **real.t** *coef* = 1. )

Add finite element matrix to left hand side.

Parameters

|           |             |                                       |
|-----------|-------------|---------------------------------------|
| <b>in</b> | <i>coef</i> | Value to multiply by the added matrix |
|-----------|-------------|---------------------------------------|

**void BodyRHS** ( **const Vect**< **real.t** > & *f* )

Add Right-Hand Side Contribution.

Parameters

|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>f</i> | Vector containing the source given function at mesh nodes |
|----|----------|-----------------------------------------------------------|

**void BoundaryRHS ( int *n*, real\_t *p* )**

Add Neumann contribution to Right-Hand Side.

Parameters

|    |          |                                                                                                                            |
|----|----------|----------------------------------------------------------------------------------------------------------------------------|
| in | <i>n</i> | Parameter to select equal to 0 if the condition is at the left end of the domain and different if it is at the right of it |
| in | <i>p</i> | Value of flux to add                                                                                                       |

Note

This member function is to be called only for the first or last element

**void setBoundaryCondition ( real\_t *f*, int *lr* )**

Set Dirichlet boundary data.

Parameters

|    |           |                                                                     |
|----|-----------|---------------------------------------------------------------------|
| in | <i>f</i>  | Value to assign                                                     |
| in | <i>lr</i> | Option to choose location of the value (-1: Left end, 1: Right end) |

**void setTraction ( real\_t *f*, int *lr* )**

Set Traction data.

Parameters

|    |           |                                                                        |
|----|-----------|------------------------------------------------------------------------|
| in | <i>f</i>  | Value of traction (Neumann boundary condition)                         |
| in | <i>lr</i> | Option to choose location of the traction (-1: Left end, 1: Right end) |

**int run ( )**

Run solution procedure This function is to be called when the constructor **Laplace1DL2(mesh,u)** is used.

Returns

return code for the solution of the linear system

**void build ( EigenProblemSolver & *e* )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |          |                                               |
|----|----------|-----------------------------------------------|
| in | <i>e</i> | Reference to used EigenProblemSolver instance |
|----|----------|-----------------------------------------------|

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

## Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.



## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

## Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|  |     |                                                               |
|--|-----|---------------------------------------------------------------|
|  | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|--|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|         |     |                                                                                 |
|---------|-----|---------------------------------------------------------------------------------|
| in      | $A$ | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in      | $b$ | Vector containing right-hand side                                               |
| in, out | $x$ | Vector containing initial guess of solution on input, actual solution on output |

### 7.51.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

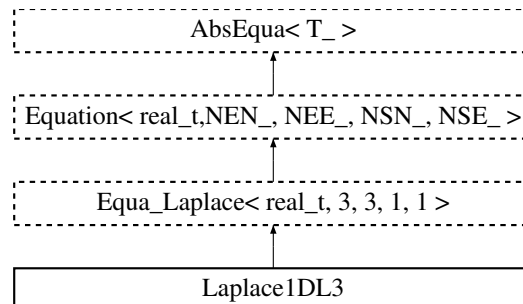
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.52 Laplace1DL3 Class Reference

To build element equation for the 1-D elliptic equation using the 3-Node line (P<sub>2</sub> ).

Inheritance diagram for Laplace1DL3:



### Public Member Functions

- [Laplace1DL3](#) ([Mesh](#) &ms, [Vect< real\\_t >](#) &u)
- [Laplace1DL3](#) ([Element](#) \*el)  
*Constructor for an element.*
- [~Laplace1DL3](#) ()  
*Destructor.*
- void [Matrix](#) ([real\\_t](#) coef=1.)  
*Add finite element matrix to left hand side.*
- void [BodyRHS](#) (const [Vect< real\\_t >](#) &f)  
*Add Right-hand side contribution.*
- void [BoundaryRHS](#) (int n, [real\\_t](#) p)  
*Add Neumann contribution to Right-Hand Side.*
- void [setTraction](#) ([real\\_t](#) f, int lr)  
*Set Traction data.*



- `int run ()`
- `virtual void build ()`  
*Solve the equation.*
- `void build (EigenProblemSolver &e)`  
*Build the linear system for an eigenvalue problem.*
- `virtual void buildEigen (int opt=0)`  
*Build matrices for an eigenvalue problem.*
- `void updateBC (const Element &el, const Vect< T_ > &bc)`  
*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< T_ > &bc)`  
*Update Right-Hand side by taking into account essential boundary conditions.*
- `void DiagBC (int dof_type=NODE.DOF, int dof=0)`  
*Update element matrix to impose bc by diagonalization technique.*
- `void LocalNodeVector (Vect< T_ > &b)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be, int dof)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< T_ > &b, LocalVect< T_, NSE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< T_ > &b, int dof_type=NODE.FIELD, int flag=0)`  
*Localize Element Vector.*
- `void SideVector (const Vect< T_ > &b)`  
*Localize Side Vector.*
- `void ElementNodeCoordinates ()`  
*Localize coordinates of element nodes.*
- `void SideNodeCoordinates ()`  
*Localize coordinates of side nodes.*
- `void ElementAssembly (Matrix< T_ > *A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (PETScMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (PETScVect< T_ > &b)`  
*Assemble element right-hand side vector into global one.*
- `void ElementAssembly (BMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SkSMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SkMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SpMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (TrMatrix< T_ > &A)`

- Assemble element matrix into global one.*
  - void [ElementAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble element vector into global one.*
  - void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)
- Assemble side matrix into global one.*
  - void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)
- Assemble side right-hand side vector into global one.*
  - void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*
  - size\_t [getNbNodes](#) () const
- Return number of element nodes.*
  - size\_t [getNbEq](#) () const
- Return number of element equations.*
  - void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*
  - [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*
  - void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*
  - [Mesh](#) & [getMesh](#) () const
- Return reference to [Mesh](#) instance.*
  - [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
  - void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)
- Choose solver for the linear system.*
  - int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > **eMat**  
*LocalMatrix* instance containing local matrix associated to current element.
- **LocalMatrix**< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > **sMat**  
*LocalMatrix* instance containing local matrix associated to current side.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **ePrev**  
*LocalVect* instance containing local vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRHS**  
*LocalVect* instance containing local right-hand side vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRes**  
*LocalVect* instance containing local residual vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NSE<sub>-</sub> > **sRHS**  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void **Init** (const **Element** \*el)  
Set element arrays to zero.
- void **Init** (const **Side** \*sd)  
Set side arrays to zero.

### 7.52.1 Detailed Description

To build element equation for the 1-D elliptic equation using the 3-Node line (P<sub>2</sub> ).

### 7.52.2 Constructor & Destructor Documentation

**Laplace1DL3** ( **Mesh** & *ms*, **Vect**< **real.t** > & *u* )

Constructor using mesh instance and solution vector

Parameters

|               |           |                                                                                  |
|---------------|-----------|----------------------------------------------------------------------------------|
| <b>in</b>     | <i>ms</i> | <b>Mesh</b> instance                                                             |
| <b>in,out</b> | <i>u</i>  | <b>Vect</b> instance that contains, after execution of <b>run()</b> the solution |

### 7.52.3 Member Function Documentation

**void Matrix** ( **real.t** *coef* = 1. )

Add finite element matrix to left hand side.

Parameters

|           |             |                                       |
|-----------|-------------|---------------------------------------|
| <b>in</b> | <i>coef</i> | Value to multiply by the added matrix |
|-----------|-------------|---------------------------------------|

**void BodyRHS** ( **const Vect**< **real.t** > & *f* )

Add Right-hand side contribution.

Parameters

|           |          |                                                            |
|-----------|----------|------------------------------------------------------------|
| <b>in</b> | <i>f</i> | Vector of right-hand side of the Poisson equation at nodes |
|-----------|----------|------------------------------------------------------------|

**void BoundaryRHS ( int *n*, real\_t *p* )**

Add Neumann contribution to Right-Hand Side.

Parameters

|           |          |                                                                                                                            |
|-----------|----------|----------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>n</i> | Parameter to select equal to 0 if the condition is at the left end of the domain and different if it is at the right of it |
| <b>in</b> | <i>p</i> | Value of flux to add                                                                                                       |

Note

This member function is to be invoked only for the first or last element

**void setTraction ( real\_t *f*, int *lr* )**

Set Traction data.

Parameters

|           |           |                                                                        |
|-----------|-----------|------------------------------------------------------------------------|
| <b>in</b> | <i>f</i>  | Value of traction (Neumann boundary condition)                         |
| <b>in</b> | <i>lr</i> | Option to choose location of the traction (-1: Left end, 1: Right end) |

**int run ( )**

Run solution procedure This function is to be called when the constructor **Laplace1DL2(mesh,u)** is used.

Returns

return code for the solution of the linear system

**void build ( EigenProblemSolver & *e* ) [inherited]**

Build the linear system for an eigenvalue problem.

Parameters

|           |          |                                               |
|-----------|----------|-----------------------------------------------|
| <b>in</b> | <i>e</i> | Reference to used EigenProblemSolver instance |
|-----------|----------|-----------------------------------------------|

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* ) [inherited]**

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>el</i> | Reference to current element instance           |
| <b>in</b> | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* ) [inherited]**

Update Right-Hand side by taking into account essential boundary conditions.

## Parameters

|    |    |                                                 |
|----|----|-------------------------------------------------|
| in | bc | Vector that contains imposed values at all DOFs |
|----|----|-------------------------------------------------|

## Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE_FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT_FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE_FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be*, int *dof* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the degree of freedom is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                           |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                             |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• NODE.FIELD, DOFs are supported by nodes [Default]</li> <li>• ELEMENT.FIELD, DOFs are supported by elements</li> <li>• SIDE.FIELD, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .             |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|      |     |                                                              |
|------|-----|--------------------------------------------------------------|
| $in$ | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|------|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.



Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

## 7.52.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

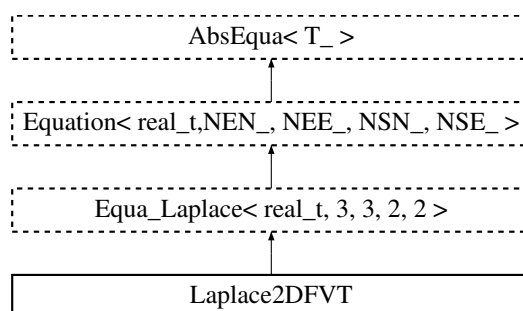
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.53 Laplace2DFVT Class Reference

To build and solve the Laplace equation using a standard Finite Volume method.

Inheritance diagram for Laplace2DFVT:



### Public Member Functions

- **Laplace2DFVT** (**Mesh** &ms, **Vect**< **real\_t** > &b, **Vect**< **real\_t** > &u)  
*Standard constructor.*
- **Laplace2DFVT** (**Mesh** &ms, **SpMatrix**< **real\_t** > &A, **Vect**< **real\_t** > &b)  
*Standard constructor.*
- **~Laplace2DFVT** ()  
*Destructor.*
- **int** **checkDelaunay** (int verb=0)  
*Check whether triangles are Delaunay ones.*
- **void** **build** (const **Vect**< **real\_t** > &f)  
*Build the linear system of equations.*
- **int** **run** (const **Vect**< **real\_t** > &f)  
*Build and solve the linear system of equations.*
- **void** **LHS** (const **Element** \*e1, const **Element** \*e2)  
*Calculate left-hand side.*
- **void** **RHS** (const **Vect**< **real\_t** > &f)  
*Add right-hand side Contribution.*
- **virtual void** **build** ()  
*Solve the equation.*
- **void** **build** (**EigenProblemSolver** &e)  
*Build the linear system for an eigenvalue problem.*
- **virtual void** **buildEigen** (int opt=0)  
*Build matrices for an eigenvalue problem.*
- **void** **updateBC** (const **Element** &el, const **Vect**< **T\_** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- **void** **updateBC** (const **Vect**< **T\_** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- **void** **DiagBC** (int dof\_type=NODE\_DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- **void** **LocalNodeVector** (**Vect**< **T\_** > &b)  
*Localize Element Vector from a Vect instance.*

- void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEE\_ > &be)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be, int dof)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NEN\_ > &be)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementSideVector](#) (const [Vect](#)< T\_ > &b, [LocalVect](#)< T\_, NSE\_ > &be)  
*Localize [Element](#) Vector from a [Vect](#) instance.*
- void [ElementVector](#) (const [Vect](#)< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize [Element](#) Vector.*
- void [SideVector](#) (const [Vect](#)< T\_ > &b)  
*Localize [Side](#) Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*

- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- real\_t [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > eMat  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > sMat  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > ePrev  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > eRes  
*[LocalVect](#) instance containing local residual vector associated to current element.*
- [LocalVect](#)< T\_, NSE\_ > sRHS  
*[LocalVect](#) instance containing local right-hand side vector associated to current side.*



## Protected Member Functions

- void [Init](#) (const [Element](#) \*el)  
*Set element arrays to zero.*
- void [Init](#) (const [Side](#) \*sd)  
*Set side arrays to zero.*

### 7.53.1 Detailed Description

To build and solve the Laplace equation using a standard Finite Volume method.

### 7.53.2 Constructor & Destructor Documentation

**Laplace2DFVT ( [Mesh](#) & *ms*, [Vect](#)< [real\\_t](#) > & *b*, [Vect](#)< [real\\_t](#) > & *u* )**

Standard constructor.

Parameters

|    |           |                                                             |
|----|-----------|-------------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance                               |
| in | <i>b</i>  | <a href="#">Vect</a> instance that contains Right-hand side |
| in | <i>u</i>  | <a href="#">Vect</a> instance that contains solution        |

**Laplace2DFVT ( [Mesh](#) & *ms*, [SpMatrix](#)< [real\\_t](#) > & *A*, [Vect](#)< [real\\_t](#) > & *b* )**

Standard constructor.

Parameters

|    |           |                                                                                                                                                        |
|----|-----------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance. The mesh must have been assigned the attribute <code>ELEMENT_DOF</code> to say that unknowns are supported by elements. |
| in | <i>A</i>  | Problem matrix to be stored in sparse format (class <a href="#">SpMatrix</a> )                                                                         |
| in | <i>b</i>  | <a href="#">Vect</a> instance that contains Right-hand side                                                                                            |

### 7.53.3 Member Function Documentation

**int checkDelaunay ( int *verb* = 0 )**

Check whether triangles are Delaunay ones.

Parameters

|    |             |                                                 |
|----|-------------|-------------------------------------------------|
| in | <i>verb</i> | Output (>0) or not (0) list of failing elements |
|----|-------------|-------------------------------------------------|

Returns

ret Number of Non Delaunay triangles

**void build ( [EigenProblemSolver](#) & *e* )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |          |                                                               |
|----|----------|---------------------------------------------------------------|
| in | <i>e</i> | Reference to used <a href="#">EigenProblemSolver</a> instance |
|----|----------|---------------------------------------------------------------|

**void updateBC ( const [Element](#) & *el*, const [Vect](#)< [T\\_](#) > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof.type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |        |                      |
|----|--------|----------------------|
| in | $exp$  | Algebraic expression |
| in | $prop$ | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem** ( **Matrix**< **T\_** > \* **A**, **Vect**< **T\_** > & **b**, **Vect**< **T\_** > & **x** ) [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

### 7.53.4 Member Data Documentation

**LocalVect**<**T\_**,**NEE\_**> **ePrev** [inherited]

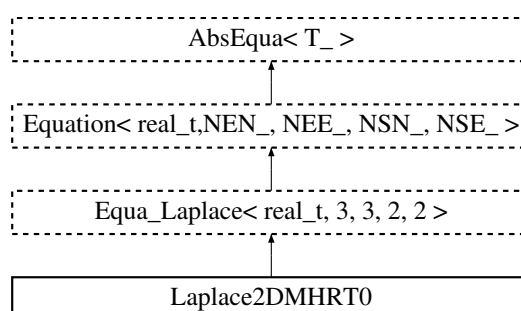
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.54 Laplace2DMHRT0 Class Reference

To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas  $RT_0$  ).

Inheritance diagram for Laplace2DMHRT0:



### Public Member Functions

- [Laplace2DMHRT0](#) ()  
*Default Constructor.*
- [Laplace2DMHRT0](#) ([Mesh](#) &**ms**, [SpMatrix](#)< [real\\_t](#) > &**A**, [Vect](#)< [real\\_t](#) > &**b**)  
*Constructor with problem data.*
- [~Laplace2DMHRT0](#) ()  
*Destructor.*
- void [setDiffusivity](#) (const [LocalMatrix](#)< [real\\_t](#), 2, 2 > &**K**)  
*Define Diffusivity (or permeability) matrix.*
- void [build](#) ()  
*Build global matrix and right-hand side.*
- void [Post](#) (const [Vect](#)< [real\\_t](#) > &**lambda**, const [Vect](#)< [real\\_t](#) > &**f**, [Vect](#)< [real\\_t](#) > &**v**, [Vect](#)< [Point](#)< [real\\_t](#) > > &**p**, [Vect](#)< [real\\_t](#) > &**u**)  
*Perform post calculations.*

- `int solve (Vect< real_t > &u)`  
*Solve the linear system of equations using the Conjugate Gradient iterative method.*
- `void build (EigenProblemSolver &e)`  
*Build the linear system for an eigenvalue problem.*
- `virtual void buildEigen (int opt=0)`  
*Build matrices for an eigenvalue problem.*
- `void updateBC (const Element &el, const Vect< T_ > &bc)`  
*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< T_ > &bc)`  
*Update Right-Hand side by taking into account essential boundary conditions.*
- `void DiagBC (int dof_type=NODE.DOF, int dof=0)`  
*Update element matrix to impose bc by diagonalization technique.*
- `void LocalNodeVector (Vect< T_ > &b)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be, int dof)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< T_ > &b, LocalVect< T_, NEN_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< T_ > &b, LocalVect< T_, NSE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< T_ > &b, int dof_type=NODE.FIELD, int flag=0)`  
*Localize Element Vector.*
- `void SideVector (const Vect< T_ > &b)`  
*Localize Side Vector.*
- `void ElementNodeCoordinates ()`  
*Localize coordinates of element nodes.*
- `void SideNodeCoordinates ()`  
*Localize coordinates of side nodes.*
- `void ElementAssembly (Matrix< T_ > *A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (PETScMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (PETScVect< T_ > &b)`  
*Assemble element right-hand side vector into global one.*
- `void ElementAssembly (BMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SkSMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SkMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (SpMatrix< T_ > &A)`  
*Assemble element matrix into global one.*
- `void ElementAssembly (TrMatrix< T_ > &A)`  
*Assemble element matrix into global one.*

- void [ElementAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< T\_ > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > [eMat](#)  
*LocalMatrix* instance containing local matrix associated to current element.
- [LocalMatrix](#)< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > [sMat](#)  
*LocalMatrix* instance containing local matrix associated to current side.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [ePrev](#)  
*LocalVect* instance containing local vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRes](#)  
*LocalVect* instance containing local residual vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NSE<sub>-</sub> > [sRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void [Init](#) (const [Element](#) \*el)  
Set element arrays to zero.
- void [Init](#) (const [Side](#) \*sd)  
Set side arrays to zero.

### 7.54.1 Detailed Description

To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas RT<sub>0</sub> ).

### 7.54.2 Constructor & Destructor Documentation

#### [Laplace2DMHRT0](#) ( )

Default Constructor.

Constructs an empty equation.

#### [Laplace2DMHRT0](#) ( [Mesh](#) & *ms*, [SpMatrix](#)< real.t > & *A*, [Vect](#)< real.t > & *b* )

Constructor with problem data.

Parameters

|    |           |                                                                                            |
|----|-----------|--------------------------------------------------------------------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance                                                              |
| in | <i>A</i>  | Problem matrix in Sparse format. This matrix must be zeroed before calling the constructor |
| in | <i>b</i>  | Problem right-hand side                                                                    |

### 7.54.3 Member Function Documentation

#### void [setDiffusivity](#) ( const [LocalMatrix](#)< real.t, 2, 2 > & *K* )

Define Diffusivity (or permeability) matrix.

By default (if this function is not called) the identity matrix (Laplace equation) is used.

Parameters

|    |     |                                                                                                 |
|----|-----|-------------------------------------------------------------------------------------------------|
| in | $K$ | Diffusivity matrix as <a href="#">LocalMatrix</a> instance. Must be symmetric positive definite |
|----|-----|-------------------------------------------------------------------------------------------------|

**void build ( )** [virtual]

Build global matrix and right-hand side.

The problem matrix and right-hand side are the ones used in the constructor. They are updated in this member function.

Reimplemented from [Equa.Laplace< real.t, 3, 3, 2, 2 >](#).

**void Post ( const Vect< real.t > & *lambda*, const Vect< real.t > & *f*, Vect< real.t > & *v*, Vect< Point< real.t > > & *p*, Vect< real.t > & *u* )**

Perform post calculations.

Parameters

|    |               |                                                               |
|----|---------------|---------------------------------------------------------------|
| in | <i>lambda</i> | Solution (Lagrange multiplier) calculated at edges            |
| in | <i>f</i>      | Vector containing the right-hand side of the Laplace equation |
| in | <i>v</i>      | Vector containing solution at mesh nodes                      |
| in | <i>p</i>      | Vector containing gradient at elements                        |
| in | <i>u</i>      | Vector containing solution at elements                        |

**int solve ( Vect< real.t > & *u* )**

Solve the linear system of equations using the Conjugate Gradient iterative method.

The matrix is preconditioned by an ILU method.

Parameters

|     |          |                                                                                                            |
|-----|----------|------------------------------------------------------------------------------------------------------------|
| out | <i>u</i> | Vector containing the solution at all sides (Sides where boundary conditions are prescribed are included). |
|-----|----------|------------------------------------------------------------------------------------------------------------|

Returns

Number of performed iterations in the CG method. Note that the maximal number is 1000 and the tolerance is  $1.e-8$

**void build ( EigenProblemSolver & *e* )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |          |                                               |
|----|----------|-----------------------------------------------|
| in | <i>e</i> | Reference to used EigenProblemSolver instance |
|----|----------|-----------------------------------------------|

**void updateBC ( const Element & *el*, const Vect< T. > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>el</code> | Reference to current element instance           |
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & bc )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |
|-----------------|-----------------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int dof\_type = NODE\_DOF, int dof = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|                 |                       |                                                                                                                                                                                                                                                                                                                  |
|-----------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>dof_type</code> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE_FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT_FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE_FIELD</code>, DOFs are supported by sides</li> </ul> |
| <code>in</code> | <code>dof</code>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|                 |                |                                                                                                                                                                                                                        |
|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>b</code> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters



|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $el$ | Reference to <a href="#">Element</a> instance                 |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |      |                                                               |
|-----|------|---------------------------------------------------------------|
| in  | $sd$ | Reference to <a href="#">Side</a> instance                    |
| in  | $x$  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | $b$  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |        |                      |
|----|--------|----------------------|
| in | $exp$  | Algebraic expression |
| in | $prop$ | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

#### 7.54.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

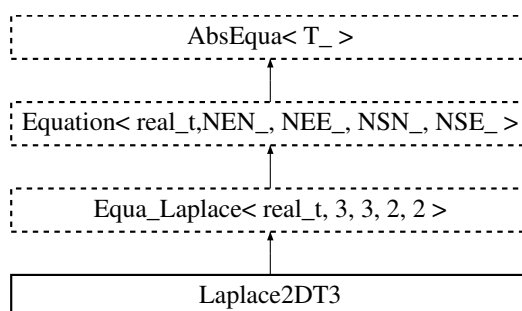
This vector has been stored as the one at previous iteration or previous time step



## 7.55 Laplace2DT3 Class Reference

To build element equation for the Laplace equation using the 2-D triangle element ( $P_1$  ).

Inheritance diagram for Laplace2DT3:



### Public Member Functions

- [Laplace2DT3](#) ([Mesh](#) &ms)  
*Constructor with mesh.*
- [Laplace2DT3](#) ([Mesh](#) &ms, [SpMatrix](#)< [real\\_t](#) > &A, [Vect](#)< [real\\_t](#) > &b)  
*Constructor with problem data.*
- [Laplace2DT3](#) ([Mesh](#) &ms, [Vect](#)< [real\\_t](#) > &b)  
*Constructor using mesh and solution vector.*
- [Laplace2DT3](#) ([Element](#) \*el)  
*Constructor for an element.*
- [Laplace2DT3](#) ([Side](#) \*sd)  
*Constructor for a side.*
- [~Laplace2DT3](#) ()  
*Destructor.*
- void [LHS](#) ([real\\_t](#) coef=1.)  
*Add finite element matrix to left-hand side.*
- void [BodyRHS](#) (const [Vect](#)< [real\\_t](#) > &f)  
*Add body source term to right-hand side.*
- void [BoundaryRHS](#) (const [Vect](#)< [real\\_t](#) > &h)  
*Add boundary source term to right-hand side.*
- void [setSource](#) (const [Vect](#)< [real\\_t](#) > &f)  
*Define Source right-hand side of the equation.*
- void [build](#) ()  
*Build global matrix and right-hand side.*
- void [buildEigen](#) (int opt=0)  
*Build global stiffness and mass matrices for the eigen system.*
- void [Post](#) (const [Vect](#)< [real\\_t](#) > &u, [Vect](#)< [Point](#)< [real\\_t](#) > > &p)  
*Perform post calculations.*
- int [solve](#) ([Vect](#)< [real\\_t](#) > &u)  
*Solve the linear system of equations using the Conjugate Gradient iterative method.*
- void [Axb](#) (const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)  
*Compute the product of the stiffness matrix by a given vector.*

- void **build** (**EigenProblemSolver** &e)  
*Build the linear system for an eigenvalue problem.*
- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble side matrix into global one.*

- void [SideAssembly](#) ([PETScVect](#)< T\_ > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)  
*Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const  
*Return number of element nodes.*
- size\_t [getNbEq](#) () const  
*Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)  
*Set initial solution (previous time step)*
- [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)  
*Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)  
*Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const  
*Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > [eMat](#)  
*LocalMatrix* instance containing local matrix associated to current element.
- [LocalMatrix](#)< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > [sMat](#)  
*LocalMatrix* instance containing local matrix associated to current side.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [ePrev](#)  
*LocalVect* instance containing local vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NEE<sub>-</sub> > [eRes](#)  
*LocalVect* instance containing local residual vector associated to current element.
- [LocalVect](#)< T<sub>-</sub>, NSE<sub>-</sub> > [sRHS](#)  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void [Init](#) (const [Element](#) \*el)  
Set element arrays to zero.
- void [Init](#) (const [Side](#) \*sd)  
Set side arrays to zero.

### 7.55.1 Detailed Description

To build element equation for the Laplace equation using the 2-D triangle element (P<sub>1</sub> ).

### 7.55.2 Constructor & Destructor Documentation

#### Laplace2DT3 ( Mesh & ms )

Constructor with mesh.  
Parameters

|    |    |                               |
|----|----|-------------------------------|
| in | ms | <a href="#">Mesh</a> instance |
|----|----|-------------------------------|

#### Laplace2DT3 ( Mesh & ms, SpMatrix< real.t > & A, Vect< real.t > & b )

Constructor with problem data.  
Parameters

|    |    |                                                                                            |
|----|----|--------------------------------------------------------------------------------------------|
| in | ms | <a href="#">Mesh</a> instance                                                              |
| in | A  | Problem matrix in Sparse format. This matrix must be zeroed before calling the constructor |
| in | b  | Problem right-hand side                                                                    |

#### Laplace2DT3 ( Mesh & ms, Vect< real.t > & b )

Constructor using mesh and solution vector.

Parameters

|    |           |                               |
|----|-----------|-------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance |
| in | <i>b</i>  | Problem right-hand side       |

### 7.55.3 Member Function Documentation

**void LHS ( real.t *coef* = 1. )**

Add finite element matrix to left-hand side.

Parameters

|    |             |                                       |
|----|-------------|---------------------------------------|
| in | <i>coef</i> | Value to multiply by the added matrix |
|----|-------------|---------------------------------------|

**void BodyRHS ( const Vect< real.t > &*f* )**

Add body source term to right-hand side.

Parameters

|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>f</i> | Vector containing the source given function at mesh nodes |
|----|----------|-----------------------------------------------------------|

**void BoundaryRHS ( const Vect< real.t > &*h* )**

Add boundary source term to right-hand side.

Parameters

|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>h</i> | Vector containing the source given function at mesh nodes |
|----|----------|-----------------------------------------------------------|

**void setSource ( const Vect< real.t > &*f* )**

Define Source right-hand side of the equation.

Parameters

|          |                                               |
|----------|-----------------------------------------------|
| <i>f</i> | [in] Vector containing source values at nodes |
|----------|-----------------------------------------------|

**void build ( )** [virtual]

Build global matrix and right-hand side.

The problem matrix and right-hand side are the ones used in the constructor. They are updated in this member function.

Reimplemented from [Equa.Laplace< real.t, 3, 3, 2, 2 >](#).

**void buildEigen ( int *opt* = 0 )** [virtual]

Build global stiffness and mass matrices for the eigen system.

Parameters

|    |            |                                                                        |
|----|------------|------------------------------------------------------------------------|
| in | <i>opt</i> | Flag to choose a lumped mass matrix (0) or consistent (1) [Default: 0] |
|----|------------|------------------------------------------------------------------------|

Reimplemented from [Equa.Laplace< real.t, 3, 3, 2, 2 >](#).

**void Post ( const Vect< real.t > &*u*, Vect< Point< real.t > > &*p* )**

Perform post calculations.

Parameters

|     |     |                                        |
|-----|-----|----------------------------------------|
| in  | $u$ | Solution at nodes                      |
| out | $p$ | Vector containing gradient at elements |

**int solve ( Vect< real\_t > &  $u$  )**

Solve the linear system of equations using the Conjugate Gradient iterative method.

The matrix is preconditioned by an ILU method.

Parameters

|    |     |                                                                                                            |
|----|-----|------------------------------------------------------------------------------------------------------------|
| in | $u$ | Vector containing the solution at all sides (Sides where boundary conditions are prescribed are included). |
|----|-----|------------------------------------------------------------------------------------------------------------|

Returns

Number of performed iterations in the CG method. Note that the maximal number is 1000 and the tolerance is  $1.e-8$

**void Axb ( const Vect< real\_t > &  $x$ , Vect< real\_t > &  $b$  )**

Compute the product of the stiffness matrix by a given vector.

Parameters

|    |     |                                          |
|----|-----|------------------------------------------|
| in | $x$ | Vector by which the matrix is multiplied |
| in | $b$ | Product vector                           |

**void build ( EigenProblemSolver &  $e$  )** [inherited]

Build the linear system for an eigenvalue problem.

Parameters

|    |     |                                               |
|----|-----|-----------------------------------------------|
| in | $e$ | Reference to used EigenProblemSolver instance |
|----|-----|-----------------------------------------------|

**void updateBC ( const Element &  $el$ , const Vect< T\_ > &  $bc$  )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |      |                                                 |
|----|------|-------------------------------------------------|
| in | $el$ | Reference to current element instance           |
| in | $bc$ | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > &  $bc$  )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |      |                                                 |
|----|------|-------------------------------------------------|
| in | $bc$ | Vector that contains imposed values at all DOFs |
|----|------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC** ( *int dof\_type* = *NODE\_DOF*, *int dof* = 0 ) [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the degree of freedom is transferred to the local vector



**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> .                                  |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                               |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <i>ePrev</i> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

## Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|  |     |                            |
|--|-----|----------------------------|
|  | $A$ | Reference to global matrix |
|--|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|  |     |                                            |
|--|-----|--------------------------------------------|
|  | $b$ | Reference to global right-hand side vector |
|--|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|          |                                                              |
|----------|--------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|           |           |                                                               |
|-----------|-----------|---------------------------------------------------------------|
| <i>in</i> | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| <i>in</i> | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |

|     |          |                                                       |
|-----|----------|-------------------------------------------------------|
| out | <i>b</i> | Global vector to add ( <a href="#">Vect</a> instance) |
|-----|----------|-------------------------------------------------------|

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.



## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|         |          |                                                                                 |
|---------|----------|---------------------------------------------------------------------------------|
| in      | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in      | <i>b</i> | Vector containing right-hand side                                               |
| in, out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

## 7.55.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

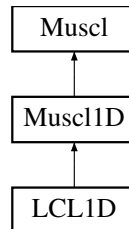
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.56 LCL1D Class Reference

Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.

Inheritance diagram for LCL1D:



### Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum `SolverType` {  
`ROE_SOLVER` = 0,  
`VFROE_SOLVER` = 1,  
`LF_SOLVER` = 2,  
`RUSANOV_SOLVER` = 3,  
`HLL_SOLVER` = 4,  
`HLLC_SOLVER` = 5,  
`MAX_SOLVER` = 6 }

*Enumeration of various solvers for the Riemann problem.*

### Public Member Functions

- `LCL1D (Mesh &m)`  
*Constructor using mesh instance.*
- `LCL1D (Mesh &m, Vect< real.t > &U)`  
*Constructor.*
- `~LCL1D ()`  
*Destructor.*
- `Vect< real.t > & getFlux ()`  
*Return sidewise fluxes.*
- `void setInitialCondition (Vect< real.t > &u)`  
*Assign initial condition by a vector.*

- void `setInitialCondition` (`real.t` u)  
*Assign a constant initial condition.*
- void `setReconstruction` ()  
*Run MUSCL reconstruction.*
- `real.t` `runOneTimeStep` ()  
*Run one time step of the linear conservation law.*
- void `setBC` (`real.t` u)  
*Set Dirichlet boundary condition.*
- void `setBC` (const `Side` &sd, `real.t` u)  
*Set Dirichlet boundary condition.*
- void `setBC` (int code, `real.t` u)  
*Set Dirichlet boundary condition.*
- void `setVelocity` (`Vect`< `real.t` > &v)  
*Set convection velocity.*
- void `setVelocity` (`real.t` v)  
*Set (constant) convection velocity.*
- void `setReferenceLength` (`real.t` dx)  
*Assign reference length value.*
- `real.t` `getReferenceLength` () const  
*Return reference length.*
- void `Forward` (const `Vect`< `real.t` > &Flux, `Vect`< `real.t` > &Field)  
*Computation of the primal variable  $n \rightarrow n+1$ .*
- `real.t` `getMeanLength` () const  
*Return mean length.*
- `real.t` `getMaximumLength` () const  
*Return maximal length.*
- `real.t` `getMinimumLength` () const  
*Return mimal length.*
- `real.t` `getTauLim` () const  
*Return mean length.*
- void `print_mesh_stat` ()  
*Output mesh information.*
- void `setTimeStep` (`real.t` dt)  
*Assign time step value.*
- `real.t` `getTimeStep` () const  
*Return time step value.*
- void `setCFL` (`real.t` CFL)  
*Assign CFL value.*
- `real.t` `getCFL` () const  
*Return CFL value.*
- `Mesh` & `getMesh` () const  
*Return reference to `Mesh` instance.*
- void `setVerbose` (int v)  
*Set verbosity parameter.*
- bool `setReconstruction` (const `Vect`< `real.t` > &U, `Vect`< `real.t` > &LU, `Vect`< `real.t` > &RU, `size.t` dof)  
*Function to reconstruct by the `Muscl` method.*

- void `setMethod` (const `Method` &s)  
*Choose a flux solver.*
- void `setSolidZoneCode` (int c)  
*Choose a code for solid zone.*
- bool `getSolidZone` () const  
*Return flag for presence of solid zones.*
- int `getSolidZoneCode` () const  
*Return code of solid zone, 0 if this one is not present.*
- void `setLimiter` (`Limiter` l)  
*Choose a flux limiter.*

### 7.56.1 Detailed Description

Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.

### 7.56.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

`FIRST_ORDER_METHOD` First Order upwind method  
`MULTI_SLOPE_Q_METHOD` Multislope Q method  
`MULTI_SLOPE_M_METHOD` Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

`MINMOD_LIMITER` MinMod limiter  
`VANLEER_LIMITER` Van Leer limiter  
`SUPERBEE_LIMITER` Superbee limiter  
`VANALBADA_LIMITER` Van Albada limiter  
`MAX_LIMITER` Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

`ROE_SOLVER` Roe solver  
`VFROE_SOLVER` Finite Volume Roe solver  
`LF_SOLVER` LF solver  
`RUSANOV_SOLVER` Rusanov solver  
`HLL_SOLVER` HLL solver  
`HLLC_SOLVER` HLLC solver  
`MAX_SOLVER` Max solver

### 7.56.3 Member Function Documentation

**void setInitialCondition ( Vect< real\_t > & *u* )**

Assign initial condition by a vector.

Parameters

|                 |                |                                     |
|-----------------|----------------|-------------------------------------|
| <code>in</code> | <code>u</code> | Vector containing initial condition |
|-----------------|----------------|-------------------------------------|

**void setInitialCondition ( `real_t u` )**

Assign a constant initial condition.

Parameters

|                 |                |                                          |
|-----------------|----------------|------------------------------------------|
| <code>in</code> | <code>u</code> | Constant value for the initial condition |
|-----------------|----------------|------------------------------------------|

**`real_t runOneTimeStep ( )`**

Run one time step of the linear conservation law.

Returns

Value of the time step

**void setBC ( `real_t u` )**

Set Dirichlet boundary condition.

Assign a constant value `u` to all boundary sides

**void setBC ( `const Side & sd`, `real_t u` )**

Set Dirichlet boundary condition.

Assign a constant value to a side

Parameters

|                 |                 |                                                   |
|-----------------|-----------------|---------------------------------------------------|
| <code>in</code> | <code>sd</code> | <a href="#">Side</a> to which value is prescribed |
| <code>in</code> | <code>u</code>  | Value to prescribe                                |

**void setBC ( `int code`, `real_t u` )**

Set Dirichlet boundary condition.

Assign a constant value sides with a given code

Parameters

|                 |                   |                                            |
|-----------------|-------------------|--------------------------------------------|
| <code>in</code> | <code>code</code> | Code of sides to which value is prescribed |
| <code>in</code> | <code>u</code>    | Value to prescribe                         |

**void setVelocity ( `Vect< real_t > & v` )**

Set convection velocity.

Parameters

|                 |                |                                                   |
|-----------------|----------------|---------------------------------------------------|
| <code>in</code> | <code>v</code> | <a href="#">Vect</a> instance containing velocity |
|-----------------|----------------|---------------------------------------------------|

**void Forward ( const Vect< real\_t > & Flux, Vect< real\_t > & Field )**

Computation of the primal variable  $n \rightarrow n+1$ .

Vector **Flux** contains elementwise fluxes issued from the Riemann problem, calculated with, as left element, **getNeighborElement(1)** and right element **getNeighborElement(2)** if **getNeighborElement(2)** doesn't exist, we are on a boundary and we prescribe a symmetry condition

**void setTimeStep ( real\_t dt )** [inherited]

Assign time step value.

Parameters

|    |           |                 |
|----|-----------|-----------------|
| in | <i>dt</i> | Time step value |
|----|-----------|-----------------|

**void setCFL ( real\_t CFL )** [inherited]

Assign CFL value.

Parameters

|    |            |              |
|----|------------|--------------|
| in | <i>CFL</i> | Value of CFL |
|----|------------|--------------|

**void setVerbose ( int v )** [inherited]

Set verbosity parameter.

Parameters

|    |          |                              |
|----|----------|------------------------------|
| in | <i>v</i> | Value of verbosity parameter |
|----|----------|------------------------------|

**bool setReconstruction ( const Vect< real\_t > & U, Vect< real\_t > & LU, Vect< real\_t > & RU, size\_t dof )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |            |                             |
|-----|------------|-----------------------------|
| in  | <i>U</i>   | Field to reconstruct        |
| out | <i>LU</i>  | Left gradient vector        |
| out | <i>RU</i>  | Right gradient vector       |
| in  | <i>dof</i> | Label of dof to reconstruct |

**void setMethod ( const Method & s )** [inherited]

Choose a flux solver.

Parameters

|    |          |                  |
|----|----------|------------------|
| in | <i>s</i> | Solver to choose |
|----|----------|------------------|

**void setLimiter ( Limiter l )** [inherited]

Choose a flux limiter.

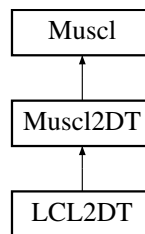
Parameters

|    |          |                   |
|----|----------|-------------------|
| in | <i>l</i> | Limiter to choose |
|----|----------|-------------------|

## 7.57 LCL2DT Class Reference

Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.

Inheritance diagram for LCL2DT:



### Public Types

- enum [Method](#) {  
[FIRST\\_ORDER\\_METHOD](#) = 0,  
[MULTI\\_SLOPE\\_Q\\_METHOD](#) = 1,  
[MULTI\\_SLOPE\\_M\\_METHOD](#) = 2 }

*Enumeration for flux choice.*

- enum [Limiter](#) {  
[MINMOD\\_LIMITER](#) = 0,  
[VANLEER\\_LIMITER](#) = 1,  
[SUPERBEE\\_LIMITER](#) = 2,  
[VANALBADA\\_LIMITER](#) = 3,  
[MAX\\_LIMITER](#) = 4 }

*Enumeration of flux limiting methods.*

- enum [SolverType](#) {  
[ROE\\_SOLVER](#) = 0,  
[VFROE\\_SOLVER](#) = 1,  
[LF\\_SOLVER](#) = 2,  
[RUSANOV\\_SOLVER](#) = 3,  
[HLL\\_SOLVER](#) = 4,  
[HLLC\\_SOLVER](#) = 5,  
[MAX\\_SOLVER](#) = 6 }

*Enumeration of various solvers for the Riemann problem.*

### Public Member Functions

- [LCL2DT](#) ([Mesh](#) &m)  
*Constructor using [Mesh](#) instance.*
- [LCL2DT](#) ([Mesh](#) &m, [Vect](#)< [real\\_t](#) > &U)  
*Constructor using mesh and initial data.*
- [~LCL2DT](#) ()  
*Destructor.*



- `Vect< real.t > & getFlux ()`  
*Return sidewise flux vector.*
- `void setInitialCondition (Vect< real.t > &u)`  
*Set elementwise initial condition.*
- `void setInitialCondition (real.t u)`  
*Set a constant initial condition.*
- `void setReconstruction ()`  
*Reconstruct flux using *Muscl* scheme.*
- `real.t runOneTimeStep ()`  
*Run one time step of the linear conservation law.*
- `void setBC (real.t u)`  
*Set Dirichlet boundary condition.*
- `void setBC (const Side &sd, real.t u)`  
*Set Dirichlet boundary condition.*
- `void setBC (int code, real.t u)`  
*Set Dirichlet boundary condition.*
- `void setVelocity (const Vect< real.t > &v)`  
*Set convection velocity.*
- `void setVelocity (const LocalVect< real.t, 2 > &v)`  
*Set (constant) convection velocity.*
- `void Forward (const Vect< real.t > &Flux, Vect< real.t > &Field)`  
*Computation of the primal variable  $n \rightarrow n+1$ .*
- `bool setReconstruction (const Vect< real.t > &U, Vect< real.t > &LU, Vect< real.t > &RU, size.t dof)`  
*Function to reconstruct by the *Muscl* method.*
- `void setTimeStep (real.t dt)`  
*Assign time step value.*
- `real.t getTimeStep () const`  
*Return time step value.*
- `void setCFL (real.t CFL)`  
*Assign CFL value.*
- `real.t getCFL () const`  
*Return CFL value.*
- `void setReferenceLength (real.t dx)`  
*Assign reference length value.*
- `real.t getReferenceLength () const`  
*Return reference length.*
- `Mesh & getMesh () const`  
*Return reference to *Mesh* instance.*
- `void setVerbose (int v)`  
*Set verbosity parameter.*
- `void setMethod (const Method &s)`  
*Choose a flux solver.*
- `void setSolidZoneCode (int c)`  
*Choose a code for solid zone.*
- `bool getSolidZone () const`  
*Return flag for presence of solid zones.*

- int `getSolidZoneCode` () const  
*Return code of solid zone, 0 if this one is not present.*
- void `setLimiter` (Limiter l)  
*Choose a flux limiter.*

## Protected Member Functions

- void `Initialize` ()  
*Construction of normals to sides.*

### 7.57.1 Detailed Description

Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.

### 7.57.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

**FIRST\_ORDER\_METHOD** First Order upwind method  
**MULTI\_SLOPE\_Q\_METHOD** Multislope Q method  
**MULTI\_SLOPE\_M\_METHOD** Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

**MINMOD\_LIMITER** MinMod limiter  
**VANLEER\_LIMITER** Van Leer limiter  
**SUPERBEE\_LIMITER** Superbee limiter  
**VANALBADA\_LIMITER** Van Albada limiter  
**MAX\_LIMITER** Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

**ROE\_SOLVER** Roe solver  
**VFROE\_SOLVER** Finite Volume Roe solver  
**LF\_SOLVER** LF solver  
**RUSANOV\_SOLVER** Rusanov solver  
**HLL\_SOLVER** HLL solver  
**HLLC\_SOLVER** HLLC solver  
**MAX\_SOLVER** Max solver

### 7.57.3 Constructor & Destructor Documentation

**LCL2DT ( Mesh &  $m$ , Vect< real\_t > &  $U$  )**

Constructor using mesh and initial data.

Parameters

|           |          |                                                  |
|-----------|----------|--------------------------------------------------|
| <i>in</i> | <i>m</i> | Reference to <a href="#">Mesh</a> instance       |
| <i>in</i> | <i>U</i> | Vector containing initial (elementwise) solution |

### 7.57.4 Member Function Documentation

**void setInitialCondition ( Vect< real\_t > & u )**

Set elementwise initial condition.

Parameters

|           |          |                                                                   |
|-----------|----------|-------------------------------------------------------------------|
| <i>in</i> | <i>u</i> | <a href="#">Vect</a> instance containing initial condition values |
|-----------|----------|-------------------------------------------------------------------|

**void setInitialCondition ( real\_t u )**

Set a constant initial condition.

Parameters

|           |          |                                                      |
|-----------|----------|------------------------------------------------------|
| <i>in</i> | <i>u</i> | Value of initial condition to assign to all elements |
|-----------|----------|------------------------------------------------------|

**real\_t runOneTimeStep ( )**

Run one time step of the linear conservation law.

Returns

Value of the time step

**void setBC ( real\_t u )**

Set Dirichlet boundary condition.

Assign a constant value u to all boundary sides

**void setBC ( const Side & sd, real\_t u )**

Set Dirichlet boundary condition.

Assign a constant value to a side

Parameters

|           |           |                                                   |
|-----------|-----------|---------------------------------------------------|
| <i>in</i> | <i>sd</i> | <a href="#">Side</a> to which value is prescribed |
| <i>in</i> | <i>u</i>  | Value to prescribe                                |

**void setBC ( int code, real\_t u )**

Set Dirichlet boundary condition.

Assign a constant value sides with a given code

Parameters

|           |             |                                            |
|-----------|-------------|--------------------------------------------|
| <i>in</i> | <i>code</i> | Code of sides to which value is prescribed |
|-----------|-------------|--------------------------------------------|

|    |     |                    |
|----|-----|--------------------|
| in | $u$ | Value to prescribe |
|----|-----|--------------------|

**void setVelocity ( const Vect< real.t > & v )**

Set convection velocity.

Parameters

|    |     |                                                   |
|----|-----|---------------------------------------------------|
| in | $v$ | <a href="#">Vect</a> instance containing velocity |
|----|-----|---------------------------------------------------|

**void setVelocity ( const LocalVect< real.t, 2 > & v )**

Set (constant) convection velocity.

Parameters

|    |     |                                                  |
|----|-----|--------------------------------------------------|
| in | $v$ | Vector containing constant velocity to prescribe |
|----|-----|--------------------------------------------------|

**void Forward ( const Vect< real.t > & Flux, Vect< real.t > & Field )**

Computation of the primal variable  $n \rightarrow n+1$ .

Vector *Flux* contains elementwise fluxes issued from the Riemann problem, calculated with, as left element, [getNeighborElement\(1\)](#) and right element [getNeighborElement\(2\)](#) if [getNeighborElement\(2\)](#) doesn't exist, we are on a boundary and we prescribe a symmetry condition

**bool setReconstruction ( const Vect< real.t > & U, Vect< real.t > & LU, Vect< real.t > & RU, size.t dof )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void Initialize ( )** [protected], [inherited]

Construction of normals to sides.

Convention: for a given side, [getPtrElement\(1\)](#) is the left element and [getPtrElement\(2\)](#) is the right element. The normal goes from left to right. For boundary sides, the normal points outward.

**void setTimeStep ( real.t dt )** [inherited]

Assign time step value.

Parameters

|    |      |                 |
|----|------|-----------------|
| in | $dt$ | Time step value |
|----|------|-----------------|

**void setCFL ( real.t CFL )** [inherited]

Assign CFL value.

Parameters

|    |            |              |
|----|------------|--------------|
| in | <i>CFL</i> | Value of CFL |
|----|------------|--------------|

**void setReferenceLength ( real.t *dx* )** [inherited]

Assign reference length value.

Parameters

|    |           |                           |
|----|-----------|---------------------------|
| in | <i>dx</i> | Value of reference length |
|----|-----------|---------------------------|

**void setVerbose ( int *v* )** [inherited]

Set verbosity parameter.

Parameters

|    |          |                              |
|----|----------|------------------------------|
| in | <i>v</i> | Value of verbosity parameter |
|----|----------|------------------------------|

**void setMethod ( const Method & *s* )** [inherited]

Choose a flux solver.

Parameters

|    |          |                  |
|----|----------|------------------|
| in | <i>s</i> | Solver to choose |
|----|----------|------------------|

**void setLimiter ( Limiter *l* )** [inherited]

Choose a flux limiter.

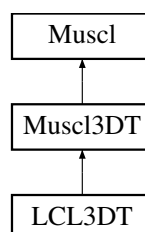
Parameters

|    |          |                   |
|----|----------|-------------------|
| in | <i>l</i> | Limiter to choose |
|----|----------|-------------------|

## 7.58 LCL3DT Class Reference

Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.

Inheritance diagram for LCL3DT:



## Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum `SolverType` {  
`ROE_SOLVER` = 0,  
`VFROE_SOLVER` = 1,  
`LF_SOLVER` = 2,  
`RUSANOV_SOLVER` = 3,  
`HLL_SOLVER` = 4,  
`HLLC_SOLVER` = 5,  
`MAX_SOLVER` = 6 }

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- `LCL3DT` (`Mesh &m`)  
*Constructor using mesh.*
- `LCL3DT` (`Mesh &m`, `Vect< real_t > &U`)  
*Constructor using mesh and initial field.*
- `~LCL3DT` ()  
*Destructor.*
- void `setInitialCondition` (`Vect< real_t > &u`)  
*Set elementwise initial condition.*
- void `setInitialCondition` (`real_t u`)  
*Set a constant initial condition.*
- void `setReconstruction` ()  
*Reconstruct flux using `Muscl` scheme.*
- `real_t` `runOneTimeStep` ()  
*Run one time step.*
- void `setBC` (`real_t u`)  
*Set Dirichlet boundary condition. Assign a constant value `u` to all boundary sides.*
- void `setBC` (`const Side &sd`, `real_t u`)  
*Set Dirichlet boundary condition.*
- void `setBC` (`int code`, `real_t u`)  
*Set Dirichlet boundary condition.*
- void `setVelocity` (`const Vect< real_t > &v`)  
*Set convection velocity.*
- void `setVelocity` (`const LocalVect< real_t, 3 > &v`)

- Set (constant) convection velocity.*

  - `void setReferenceLength (real_t dx)`  
*Assign reference length value.*
  - `real_t getReferenceLength () const`  
*Return reference length.*
  - `void Forward (const Vect< real_t > &Flux, Vect< real_t > &Field)`  
*Computation of the primal variable  $n \rightarrow n+1$ .*
  - `bool setReconstruction (const Vect< real_t > &U, Vect< real_t > &LU, Vect< real_t > &RU, size_t dof)`  
*Function to reconstruct by the *Muscl* method.*
  - `real_t getMinimumFaceArea () const`  
*Return minimum area of faces in the mesh.*
  - `real_t getMinimumElementVolume () const`  
*Return minimum volume of elements in the mesh.*
  - `real_t getMaximumFaceArea () const`  
*Return maximum area of faces in the mesh.*
  - `real_t getMaximumElementVolume () const`  
*Return maximum volume of elements in the mesh.*
  - `real_t getMeanFaceArea () const`  
*Return mean area of faces in the mesh.*
  - `real_t getMeanElementVolume () const`  
*Return mean volume of elements in the mesh.*
  - `real_t getMinimumEdgeLength () const`  
*Return minimum length of edges in the mesh.*
  - `real_t getMinimumVolumebyArea () const`  
*Return minimum volume by area in the mesh.*
  - `real_t getMaximumEdgeLength () const`  
*Return maximum length of edges in the mesh.*
  - `real_t getTauLim () const`  
*Return value of tau lim.*
  - `real_t getComega () const`  
*Return value of Comega.*
  - `void setbetalim (real_t bl)`  
*Assign value of beta lim.*
  - `void setTimeStep (real_t dt)`  
*Assign time step value.*
  - `real_t getTimeStep () const`  
*Return time step value.*
  - `void setCFL (real_t CFL)`  
*Assign CFL value.*
  - `real_t getCFL () const`  
*Return CFL value.*
  - `Mesh & getMesh () const`  
*Return reference to *Mesh* instance.*
  - `void setVerbose (int v)`  
*Set verbosity parameter.*
  - `void setMethod (const Method &s)`



- *Choose a flux solver.*  
void [setSolidZoneCode](#) (int c)
- *Choose a code for solid zone.*  
bool [getSolidZone](#) () const
- *Return flag for presence of solid zones.*  
int [getSolidZoneCode](#) () const
- *Return code of solid zone, 0 if this one is not present.*  
void [setLimiter](#) ([Limiter](#) l)
- *Choose a flux limiter.*

### 7.58.1 Detailed Description

Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.

### 7.58.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

**FIRST\_ORDER\_METHOD** First Order upwind method  
**MULTI\_SLOPE\_Q\_METHOD** Multislope Q method  
**MULTI\_SLOPE\_M\_METHOD** Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

**MINMOD\_LIMITER** MinMod limiter  
**VANLEER\_LIMITER** Van Leer limiter  
**SUPERBEE\_LIMITER** Superbee limiter  
**VANALBADA\_LIMITER** Van Albada limiter  
**MAX\_LIMITER** Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

**ROE\_SOLVER** Roe solver  
**VFROE\_SOLVER** Finite Volume Roe solver  
**LF\_SOLVER** LF solver  
**RUSANOV\_SOLVER** Rusanov solver  
**HLL\_SOLVER** HLL solver  
**HLLC\_SOLVER** HLLC solver  
**MAX\_SOLVER** Max solver

**7.58.3 Constructor & Destructor Documentation****LCL3DT ( Mesh &  $m$ , Vect< real\_t > &  $U$  )**

Constructor using mesh and initial field.

Parameters

|                 |                |                                                  |
|-----------------|----------------|--------------------------------------------------|
| <code>in</code> | <code>m</code> | Reference to <a href="#">Mesh</a> instance       |
| <code>in</code> | <code>U</code> | Vector containing initial (elementwise) solution |

### 7.58.4 Member Function Documentation

**void setInitialCondition ( Vect< real\_t > & u )**

Set elementwise initial condition.

Parameters

|                 |                |                                                                   |
|-----------------|----------------|-------------------------------------------------------------------|
| <code>in</code> | <code>u</code> | <a href="#">Vect</a> instance containing initial condition values |
|-----------------|----------------|-------------------------------------------------------------------|

**void setInitialCondition ( real\_t u )**

Set a constant initial condition.

Parameters

|                 |                |                                                      |
|-----------------|----------------|------------------------------------------------------|
| <code>in</code> | <code>u</code> | Value of initial condition to assign to all elements |
|-----------------|----------------|------------------------------------------------------|

**void setBC ( const Side & sd, real\_t u )**

Set Dirichlet boundary condition.

Assign a constant value to a side

Parameters

|                 |                 |                                                   |
|-----------------|-----------------|---------------------------------------------------|
| <code>in</code> | <code>sd</code> | <a href="#">Side</a> to which value is prescribed |
| <code>in</code> | <code>u</code>  | Value to prescribe                                |

**void setBC ( int code, real\_t u )**

Set Dirichlet boundary condition.

Assign a constant value sides with a given code

Parameters

|                 |                   |                                            |
|-----------------|-------------------|--------------------------------------------|
| <code>in</code> | <code>code</code> | Code of sides to which value is prescribed |
| <code>in</code> | <code>u</code>    | Value to prescribe                         |

**void setVelocity ( const Vect< real\_t > & v )**

Set convection velocity.

Parameters

|                 |                |                                                   |
|-----------------|----------------|---------------------------------------------------|
| <code>in</code> | <code>v</code> | <a href="#">Vect</a> instance containing velocity |
|-----------------|----------------|---------------------------------------------------|

**void setVelocity ( const LocalVect< real\_t, 3 > & v )**

Set (constant) convection velocity.

Parameters

|    |     |                                                  |
|----|-----|--------------------------------------------------|
| in | $v$ | Vector containing constant velocity to prescribe |
|----|-----|--------------------------------------------------|

**void Forward ( const Vect< real\_t > & Flux, Vect< real\_t > & Field )**

Computation of the primal variable  $n \rightarrow n+1$ .

Vector Flux contains elementwise fluxes issued from the Riemann problem, calculated with, as left element, **getNeighborElement(1)** and right element **getNeighborElement(2)** if **getNeighborElement(2)** doesn't exist, we are on a boundary and we prescribe a symmetry condition

**bool setReconstruction ( const Vect< real\_t > & U, Vect< real\_t > & LU, Vect< real\_t > & RU, size\_t dof )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void setTimeStep ( real\_t dt )** [inherited]

Assign time step value.

Parameters

|    |      |                 |
|----|------|-----------------|
| in | $dt$ | Time step value |
|----|------|-----------------|

**void setCFL ( real\_t CFL )** [inherited]

Assign CFL value.

Parameters

|    |       |              |
|----|-------|--------------|
| in | $CFL$ | Value of CFL |
|----|-------|--------------|

**void setVerbose ( int v )** [inherited]

Set verbosity parameter.

Parameters

|    |     |                              |
|----|-----|------------------------------|
| in | $v$ | Value of verbosity parameter |
|----|-----|------------------------------|

**void setMethod ( const Method & s )** [inherited]

Choose a flux solver.

Parameters

|    |   |                  |
|----|---|------------------|
| in | s | Solver to choose |
|----|---|------------------|

**void setLimiter ( Limiter l )** [inherited]

Choose a flux limiter.

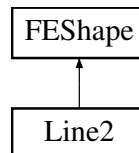
Parameters

|    |   |                   |
|----|---|-------------------|
| in | l | Limiter to choose |
|----|---|-------------------|

## 7.59 Line2 Class Reference

To describe a 2-Node planar line finite element.

Inheritance diagram for Line2:



### Public Member Functions

- [Line2](#) ()  
*Default Constructor.*
- [Line2](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [Line2](#) (const [Side](#) \*side)  
*Constructor for a side.*
- [Line2](#) (const [Edge](#) \*edge)  
*Constructor for an edge.*
- [~Line2](#) ()  
*Destructor.*
- [real\\_t](#) [getLength](#) () const  
*Return element length.*
- [Point](#)< [real\\_t](#) > [getNormal](#) () const  
*Return unit normal vector to line.*
- [Point](#)< [real\\_t](#) > [getTangent](#) () const  
*Return unit tangent vector to line.*
- [real\\_t](#) [Sh](#) (size\_t i, [real\\_t](#) s) const  
*Calculate shape function of a given node at a given point.*
- [real\\_t](#) [DSh](#) (size\_t i) const  
*Calculate partial derivative of shape function of a node.*
- [Point](#)< [real\\_t](#) > [getRefCoord](#) (const [Point](#)< [real\\_t](#) > &x)  
*Return reference coordinates of a point x in element.*
- bool [isIn](#) (const [Point](#)< [real\\_t](#) > &x)  
*Check whether point x is in current line element or not.*
- [real\\_t](#) [getInterpolate](#) (const [Point](#)< [real\\_t](#) > &x, const [LocalVect](#)< [real\\_t](#), 2 > &v)

- Return interpolated value at a given point.*

  - `real_t Sh (size_t i) const`

*Return shape function of node  $i$  at given point.*
- `real_t Sh (size_t i, Point< real_t > s) const`

*Calculate shape function of node  $i$  at a given point  $s$ .*
- `real_t getDet () const`

*Return determinant of jacobian.*
- `Point< real_t > getCenter () const`

*Return coordinates of center of element.*
- `Point< real_t > getLocalPoint () const`

*Localize a point in the element.*
- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`

*Localize a point in the element.*

### 7.59.1 Detailed Description

To describe a 2-Node planar line finite element.

Defines geometric quantities associated to 2-node linear segment element  $P_1$  in the space. The reference element is the segment  $[-1, 1]$ . Note that the line length is not checked unless the function check is called.

### 7.59.2 Constructor & Destructor Documentation

**Line2 ( const Element \* *el* )**

Constructor for an element.  
Parameters

|    |           |                    |
|----|-----------|--------------------|
| in | <i>el</i> | Pointer to element |
|----|-----------|--------------------|

**Line2 ( const Side \* *side* )**

Constructor for a side.  
Parameters

|    |             |                 |
|----|-------------|-----------------|
| in | <i>side</i> | Pointer to side |
|----|-------------|-----------------|

**Line2 ( const Edge \* *edge* )**

Constructor for an edge.  
Parameters

|    |             |                 |
|----|-------------|-----------------|
| in | <i>edge</i> | Pointer to edge |
|----|-------------|-----------------|

### 7.59.3 Member Function Documentation

**real\_t Sh ( size\_t *i*, real\_t *s* ) const**

Calculate shape function of a given node at a given point.

Parameters

|    |          |                                                                          |
|----|----------|--------------------------------------------------------------------------|
| in | <i>i</i> | <a href="#">Node</a> number (1 or 2).                                    |
| in | <i>s</i> | Localization of point in natural coordinates (must be between -1 and 1). |

**real\_t DSh ( size\_t *i* ) const**

Calculate partial derivative of shape function of a node.

Parameters

|    |          |                                       |
|----|----------|---------------------------------------|
| in | <i>i</i> | <a href="#">Node</a> number (1 or 2). |
|----|----------|---------------------------------------|

**Point<real\_t> getRefCoord ( const Point< real\_t > & *x* )**

Return reference coordinates of a point *x* in element.

Only the x-coordinate of the returned value has a meaning

**real\_t getInterpolate ( const Point< real\_t > & *x*, const LocalVect< real\_t, 2 > & *v* )**

Return interpolated value at a given point.

Parameters

|     |          |                                                                                    |
|-----|----------|------------------------------------------------------------------------------------|
| in  | <i>x</i> | <a href="#">Point</a> where interpolation is evaluated (in the reference element). |
| out | <i>v</i> | Computed value.                                                                    |

**real\_t Sh ( size\_t *i*, Point< real\_t > *s* ) const** [inherited]

Calculate shape function of node *i* at a given point *s*.

Parameters

|    |          |                                                                                       |
|----|----------|---------------------------------------------------------------------------------------|
| in | <i>i</i> | Local node label                                                                      |
| in | <i>s</i> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & *s* ) const** [inherited]

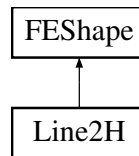
Localize a point in the element.

Return actual coordinates where *s* are coordinates in the reference element.

## 7.60 Line2H Class Reference

To describe a 2-Node Hermite planar line finite element.

Inheritance diagram for Line2H:



### Public Member Functions

- [Line2H](#) ()  
*Default Constructor.*
- [Line2H](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [Line2H](#) (const [Side](#) \*side)  
*Constructor for a side.*
- [~Line2H](#) ()  
*Destructor.*
- [Point](#)< [real\\_t](#) > [getLocalPoint](#) ([real\\_t](#) s) const  
*Localize a point in the element.*
- [real\\_t](#) [Sh](#) (size\_t i, [real\\_t](#) s) const  
*Return shape function value of node i at given point s*
- [real\\_t](#) [DSh](#) (size\_t i, [real\\_t](#) s) const  
*Return first derivative (along the abscissa) of shape function of node i at a given point.*
- [real\\_t](#) [D2Sh](#) (size\_t i, [real\\_t](#) s) const  
*Return second derivatives (along the abscissa) of shape function of node i*
- [real\\_t](#) [getDet](#) () const  
*Return determinant of jacobian.*
- [real\\_t](#) [getLength](#) ()  
*Return element length.*
- [real\\_t](#) [check](#) () const  
*Check line length and number of line nodes.*
- [real\\_t](#) [Sh](#) (size\_t i) const  
*Return shape function of node i at given point.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node i at a given point s.*
- [Point](#)< [real\\_t](#) > [DSh](#) (size\_t i) const  
*Return derivatives of shape function of node i at a given point.*
- [Point](#)< [real\\_t](#) > [getCenter](#) () const  
*Return coordinates of center of element.*
- [Point](#)< [real\\_t](#) > [getLocalPoint](#) () const  
*Localize a point in the element.*
- [Point](#)< [real\\_t](#) > [getLocalPoint](#) (const [Point](#)< [real\\_t](#) > &s) const  
*Localize a point in the element.*



### 7.60.1 Detailed Description

To describe a 2-Node Hermite planar line finite element.

Defines geometric quantities associated to 2-node segment element in the space using Hermite ( $C^1$ ) interpolation. The interpolation functions are polynomials of degree 3. The reference element is the segment  $[-1, 1]$ . The unknowns are supported by extremities of the interval: each extremity supports two unknowns, the function and its line derivative.

### 7.60.2 Member Function Documentation

**Point<real\_t> getLocalPoint ( real\_t s ) const**

Localize a point in the element.

For a point  $s$  in the reference element, return coordinates in the real element.

**real\_t check ( ) const**

Check line length and number of line nodes.

Returns

- $> 0$ :  $m$  is the length
- $= 0$ : zero length ( $\Rightarrow$  Error)

**real\_t Sh ( size\_t i, Point< real\_t > s ) const** [inherited]

Calculate shape function of node  $i$  at a given point  $s$ .

Parameters

|    |     |                                                                                       |
|----|-----|---------------------------------------------------------------------------------------|
| in | $i$ | Local node label                                                                      |
| in | $s$ | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**Point<real\_t> DSh ( size\_t i ) const** [inherited]

Return derivatives of shape function of node  $i$  at a given point.

If the transformation (Reference element  $\rightarrow$  Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

Parameters

|    |     |                                      |
|----|-----|--------------------------------------|
| in | $i$ | Partial derivative index (1, 2 or 3) |
|----|-----|--------------------------------------|

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element  $\rightarrow$  Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

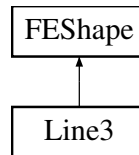
Localize a point in the element.

Return actual coordinates where  $s$  are coordinates in the reference element.

## 7.61 Line3 Class Reference

To describe a 3-Node quadratic planar line finite element.

Inheritance diagram for Line3:



### Public Member Functions

- [Line3](#) ()  
*Default Constructor.*
- [Line3](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [Line3](#) (const [Side](#) \*sd)  
*Constructor for a side.*
- [~Line3](#) ()  
*Destructor.*
- void [setLocal](#) ([real\\_t](#) s)  
*Initialize local point coordinates in element.*
- [real\\_t](#) [DSh](#) (size\_t i) const  
*Return derivatives of shape function of node i at a given point.*
- [Point](#)< [real\\_t](#) > [getLocalPoint](#) () const  
*Return actual coordinates of localized point.*
- [real\\_t](#) [Sh](#) (size\_t i) const  
*Return shape function of node i at given point.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node i at a given point s.*
- [real\\_t](#) [getDet](#) () const  
*Return determinant of jacobian.*
- [Point](#)< [real\\_t](#) > [getCenter](#) () const  
*Return coordinates of center of element.*
- [Point](#)< [real\\_t](#) > [getLocalPoint](#) (const [Point](#)< [real\\_t](#) > &s) const  
*Localize a point in the element.*

### 7.61.1 Detailed Description

To describe a 3-Node quadratic planar line finite element.

Defines geometric quantities associated to 3-node quadratic element  $P_2$  in the space. The reference element is the segment  $[-1, 1]$ . The user must take care to the fact that determinant of jacobian and other quantities depend on the point in the reference element where they are calculated. For this, before any utilization of shape functions or jacobian, function [setLocal\(\)](#) must be invoked.

[Element](#) nodes are ordered as the following: the left one, the central one and the right one.

### 7.61.2 Member Function Documentation

`real_t Sh ( size_t i, Point< real_t > s ) const` [inherited]

Calculate shape function of node `i` at a given point `s`.

Parameters

|    |          |                                                                                       |
|----|----------|---------------------------------------------------------------------------------------|
| in | <i>i</i> | Local node label                                                                      |
| in | <i>s</i> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.62 LocalMatrix< T\_, NR\_, NC\_ > Class Template Reference

Handles small size matrices like element matrices, with a priori known size.

### Public Member Functions

- [LocalMatrix](#) ()  
*Default constructor.*
- [LocalMatrix](#) (const [LocalMatrix](#)< T\_, NR\_, NC\_ > &m)  
*Copy constructor.*
- [LocalMatrix](#) ([Element](#) \*el, const [SpMatrix](#)< T\_ > &a)  
*Constructor of a local matrix associated to element from a [SpMatrix](#).*
- [LocalMatrix](#) ([Element](#) \*el, const [SkMatrix](#)< T\_ > &a)  
*Constructor of a local matrix associated to element from a [SkMatrix](#).*
- [LocalMatrix](#) ([Element](#) \*el, const [SkSMatrix](#)< T\_ > &a)  
*Constructor of a local matrix associated to element from a [SkSMatrix](#).*
- [~LocalMatrix](#) ()  
*Destructor.*
- T\_ & [operator\(\)](#) (size\_t i, size\_t j)  
*Operator () (Non constant version)*
- T\_ [operator\(\)](#) (size\_t i, size\_t j) const  
*Operator () (Constant version)*
- void [Localize](#) ([Element](#) \*el, const [SpMatrix](#)< T\_ > &a)  
*Initialize matrix as element matrix from global [SpMatrix](#).*
- void [Localize](#) ([Element](#) \*el, const [SkMatrix](#)< T\_ > &a)  
*Initialize matrix as element matrix from global [SkMatrix](#).*
- void [Localize](#) ([Element](#) \*el, const [SkSMatrix](#)< T\_ > &a)  
*Initialize matrix as element matrix from global [SkSMatrix](#).*
- [LocalMatrix](#)< T\_, NR\_, NC\_ > & [operator=](#) (const [LocalMatrix](#)< T\_, NR\_, NC\_ > &m)  
*Operator =*
- [LocalMatrix](#)< T\_, NR\_, NC\_ > & [operator=](#) (const T\_ &x)  
*Operator =*

- `LocalMatrix< T_, NR_, NC_ > & operator+=` (const `LocalMatrix< T_, NR_, NC_ > &m`)  
*Operator +=*
- `LocalMatrix< T_, NR_, NC_ > & operator-=` (const `LocalMatrix< T_, NR_, NC_ > &m`)  
*Operator -=*
- `LocalVect< T_, NR_ > operator*` (`LocalVect< T_, NC_ > &x`)  
*Operator \**
- `LocalMatrix< T_, NR_, NC_ > & operator+=` (const `T_ &x`)  
*Operator +=*
- `LocalMatrix< T_, NR_, NC_ > & operator-=` (const `T_ &x`)  
*Operator -=*
- `LocalMatrix< T_, NR_, NC_ > & operator*=` (const `T_ &x`)  
*Operator \*=*
- `LocalMatrix< T_, NR_, NC_ > & operator/=` (const `T_ &x`)  
*Operator /=*
- `void MultAdd` (const `LocalVect< T_, NC_ > &x`, `LocalVect< T_, NR_ > &y`)  
*Multiply matrix by vector and add result to vector.*
- `void MultAddScal` (const `T_ &a`, const `LocalVect< T_, NC_ > &x`, `LocalVect< T_, NR_ > &y`)  
*Multiply matrix by scaled vector and add result to vector.*
- `void Mult` (const `LocalVect< T_, NC_ > &x`, `LocalVect< T_, NR_ > &y`)  
*Multiply matrix by vector.*
- `void Symmetrize` ()  
*Symmetrize matrix.*
- `int Factor` ()  
*Factorize matrix.*
- `int Solve` (`LocalVect< T_, NR_ > &b`)  
*Forward and backsubstitute to solve a linear system.*
- `int FactorAndSolve` (`LocalVect< T_, NR_ > &b`)  
*Factorize matrix and solve linear system.*
- `void Invert` (`LocalMatrix< T_, NR_, NC_ > &A`)  
*Calculate inverse of matrix.*
- `T_ getInnerProduct` (const `LocalVect< T_, NC_ > &x`, const `LocalVect< T_, NR_ > &y`)  
*Calculate inner product with respect to matrix.*
- `T_ * get` ()  
*Return pointer to matrix as a C-array.*

### 7.62.1 Detailed Description

**template<class T\_, size\_t NR\_, size\_t NC\_>class OFELI::LocalMatrix< T\_, NR\_, NC\_ >**

Handles small size matrices like element matrices, with a priori known size.

The template class `LocalMatrix` treats small size matrices. Typically, this class is recommended to store element and side arrays.

Internally, no dynamic storage is used.

Template Parameters

|            |                                                 |
|------------|-------------------------------------------------|
| <i>T_</i>  | Data type (double, float, complex<double>, ...) |
| <i>NR_</i> | number of rows of matrix                        |
| <i>NC_</i> | number of columns of matrix                     |

### 7.62.2 Constructor & Destructor Documentation

#### LocalMatrix ( )

Default constructor.

Constructs a matrix with 0 rows and 0 columns

#### LocalMatrix ( Element \* *el*, const SpMatrix< T\_ > & *a* )

Constructor of a local matrix associated to element from a [SpMatrix](#).

Parameters

|    |           |                                                               |
|----|-----------|---------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                            |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SpMatrix</a> . |

#### LocalMatrix ( Element \* *el*, const SkMatrix< T\_ > & *a* )

Constructor of a local matrix associated to element from a [SkMatrix](#).

Parameters

|    |           |                                                               |
|----|-----------|---------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                            |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SkMatrix</a> . |

#### LocalMatrix ( Element \* *el*, const SkSMatrix< T\_ > & *a* )

Constructor of a local matrix associated to element from a [SkSMatrix](#).

Parameters

|    |           |                                                                |
|----|-----------|----------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                             |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SkSMatrix</a> . |

### 7.62.3 Member Function Documentation

#### T\_& operator() ( size\_t *i*, size\_t *j* )

Operator ( ) (Non constant version)

Returns entry at row *i* and column *j*.

#### T\_ operator() ( size\_t *i*, size\_t *j* ) const

Operator ( ) (Constant version)

Returns entry at row *i* and column *j*.

#### void Localize ( Element \* *el*, const SpMatrix< T\_ > & *a* )

Initialize matrix as element matrix from global [SpMatrix](#).

Parameters

|    |           |                                                                                                                         |
|----|-----------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                                                                                      |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SpMatrix</a> . This function is called by its corresponding constructor. |

**void Localize ( Element \* *el*, const SkMatrix< T<sub>-</sub> > & *a* )**

Initialize matrix as element matrix from global [SkMatrix](#).

Parameters

|    |           |                                                                                                                         |
|----|-----------|-------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                                                                                      |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SkMatrix</a> . This function is called by its corresponding constructor. |

**void Localize ( Element \* *el*, const SkSMatrix< T<sub>-</sub> > & *a* )**

Initialize matrix as element matrix from global [SkSMatrix](#).

Parameters

|    |           |                                                                                                                          |
|----|-----------|--------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a>                                                                                       |
| in | <i>a</i>  | Global matrix as instance of class <a href="#">SkSMatrix</a> . This function is called by its corresponding constructor. |

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator= ( const LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & *m* )**

Operator =

Copy instance *m* into current instance.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator= ( const T<sub>-</sub> & *x* )**

Operator =

Assign matrix to identity times *x*

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator+= ( const LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & *m* )**

Operator +=

Add *m* to current matrix.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator-= ( const LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & *m* )**

Operator -=

Subtract *m* from current matrix.

**LocalVect< T<sub>-</sub>, NR<sub>-</sub> > operator\* ( LocalVect< T<sub>-</sub>, NC<sub>-</sub> > & *x* )**

Operator \*

Return a [Vect](#) instance as product of current matrix by vector *x*.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator+= ( const T<sub>-</sub> & *x* )**

Operator +=

Add constant *x* to current matrix entries.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator-= ( const T<sub>-</sub> & x )**

Operator -=

Subtract x from current matrix entries.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator\*= ( const T<sub>-</sub> & x )**

Operator \*=

Multiply matrix entries by constant x.

**LocalMatrix< T<sub>-</sub>, NR<sub>-</sub>, NC<sub>-</sub> > & operator/= ( const T<sub>-</sub> & x )**

Operator /=

Divide by x current matrix entries.

**void MultAdd ( const LocalVect< T<sub>-</sub>, NC<sub>-</sub> > & x, LocalVect< T<sub>-</sub>, NR<sub>-</sub> > & y )**

Multiply matrix by vector and add result to vector.

Parameters

|     |          |                                                      |
|-----|----------|------------------------------------------------------|
| in  | <i>x</i> | Vector to multiply matrix by.                        |
| out | <i>y</i> | Resulting vector ( <i>y</i> += <i>a</i> * <i>x</i> ) |

**void MultAddScal ( const T<sub>-</sub> & a, const LocalVect< T<sub>-</sub>, NC<sub>-</sub> > & x, LocalVect< T<sub>-</sub>, NR<sub>-</sub> > & y )**

Multiply matrix by scaled vector and add result to vector.

Parameters

|     |          |                                                      |
|-----|----------|------------------------------------------------------|
| in  | <i>a</i> | Constant to premultiply by vector x.                 |
| in  | <i>x</i> | (Scaled) vector to multiply matrix by.               |
| out | <i>y</i> | Resulting vector ( <i>y</i> += <i>a</i> * <i>x</i> ) |

**void Mult ( const LocalVect< T<sub>-</sub>, NC<sub>-</sub> > & x, LocalVect< T<sub>-</sub>, NR<sub>-</sub> > & y )**

Multiply matrix by vector.

Parameters

|     |          |                               |
|-----|----------|-------------------------------|
| in  | <i>x</i> | Vector to multiply matrix by. |
| out | <i>y</i> | Resulting vector.             |

**void Symmetrize ( )**

Symmetrize matrix.

Fill upper triangle to form a symmetric matrix.

**int Factor ( )**

Factorize matrix.

Performs a LU factorization.

Returns

- 0: Factorization has ended normally,
- n: n-th pivot was zero.



**int Solve ( LocalVect< T\_, NR\_ > & b )**

Forward and backsubstitute to solve a linear system.

Parameters

|    |     |                                                         |
|----|-----|---------------------------------------------------------|
| in | $b$ | Right-hand side in input and solution vector in output. |
|----|-----|---------------------------------------------------------|

Returns

- 0: Solution was performed normally.
- n: n-th pivot is zero.

Note

Matrix must have been factorized at first.

**int FactorAndSolve ( LocalVect< T\_, NR\_ > &  $b$  )**

Factorize matrix and solve linear system.

Parameters

|        |     |                                                         |
|--------|-----|---------------------------------------------------------|
| in,out | $b$ | Right-hand side in input and solution vector in output. |
|--------|-----|---------------------------------------------------------|

Returns

0 if solution was performed normally. n if n-th pivot is zero. This function simply calls [Factor\(\)](#) then [Solve\(b\)](#).

**void Invert ( LocalMatrix< T\_, NR\_, NC\_ > &  $A$  )**

Calculate inverse of matrix.

Parameters

|     |     |                   |
|-----|-----|-------------------|
| out | $A$ | Inverse of matrix |
|-----|-----|-------------------|

**T\_ getInnerProduct ( const LocalVect< T\_, NC\_ > &  $x$ , const LocalVect< T\_, NR\_ > &  $y$  )**

Calculate inner product with respect to matrix.

Returns the product  $x^T Ay$

Parameters

|    |     |              |
|----|-----|--------------|
| in | $x$ | Left vector  |
| in | $y$ | Right vector |

Returns

Resulting product

## 7.63 LocalVect< T\_, N\_ > Class Template Reference

Handles small size vectors like element vectors.

## Public Member Functions

- **LocalVect** ()  
*Default constructor.*
- **LocalVect** (const T\_ \*a)  
*Constructor using a C-array.*
- **LocalVect** (const **Element** \*el)  
*Constructor using **Element** pointer.*
- **LocalVect** (const **Side** \*sd)  
*Constructor using **Side** pointer.*
- **LocalVect** (const **LocalVect**< T\_, N\_ > &v)  
*Copy constructor.*
- **LocalVect** (const **Element** \*el, const **Vect**< T\_ > &v, int opt=0)  
*Constructor of an element vector from a global **Vect** instance.*
- **LocalVect** (const **Side** \*sd, const **Vect**< T\_ > &v, int opt=0)  
*Constructor of a side vector from a global **Vect** instance.*
- **~LocalVect** ()  
*Destructor.*
- void **getLocal** (const **Element** &el, const **Vect**< T\_ > &v, int type)  
*Localize an element vector from a global **Vect** instance.*
- void **Localize** (const **Element** \*el, const **Vect**< T\_ > &v, size\_t k=0)  
*Localize an element vector from a global **Vect** instance.*
- void **Localize** (const **Side** \*sd, const **Vect**< T\_ > &v, size\_t k=0)  
*Localize a side vector from a global **Vect** instance.*
- T\_ & **operator[]** (size\_t i)  
*Operator [] (Non constant version).*
- T\_ **operator[]** (size\_t i) const  
*Operator [] (Constant version).*
- T\_ & **operator()** (size\_t i)  
*Operator () (Non constant version).*
- T\_ **operator()** (size\_t i) const  
*Operator () (Constant version).*
- **Element** \* **El** ()  
*Return pointer to **Element** if vector was constructed using an element and NULL otherwise.*
- **Side** \* **Sd** ()  
*Return pointer to **Side** if vector was constructed using a side and NULL otherwise.*
- **LocalVect**< T\_, N\_ > & **operator=** (const **LocalVect**< T\_, N\_ > &v)  
*Operator =*
- **LocalVect**< T\_, N\_ > & **operator=** (const T\_ &x)  
*Operator =*
- **LocalVect**< T\_, N\_ > & **operator+=** (const **LocalVect**< T\_, N\_ > &v)  
*Operator +=*
- **LocalVect**< T\_, N\_ > & **operator+=** (const T\_ &a)  
*Operator +=*
- **LocalVect**< T\_, N\_ > & **operator-=** (const **LocalVect**< T\_, N\_ > &v)  
*Operator -=*
- **LocalVect**< T\_, N\_ > & **operator-=** (const T\_ &a)

- Operator -=*
- `LocalVect< T-, N- > & operator*= (const T- &a)`
- Operator \*=*
- `LocalVect< T-, N- > & operator/= (const T- &a)`
- Operator /=*
- `T- * get ()`
- Return pointer to vector as a C-Array.*
- `T- operator, (const LocalVect< T-, N- > &v) const`
- Return Dot (scalar) product of two vectors.*

### 7.63.1 Detailed Description

**template<class T<sub>-</sub>, size\_t N<sub>-</sub>>class OFELI::LocalVect< T<sub>-</sub>, N<sub>-</sub> >**

Handles small size vectors like element vectors.

The template class `LocalVect` treats small size vectors. Typically, this class is recommended to store element and side arrays. Operators `=`, `[]` and `()` are overloaded so that one can write for instance:

```
LocalVect<double,10> u, v;
v = -1.0;
u = v;
u(3) = -2.0;
```

to set vector `v` entries to `-1`, copy vector `v` into vector `u` and assign third entry of `v` to `-2`. Notice that entries of `v` are here `v(1)`, `v(2)`, ..., `v(10)`, *i.e.* vector entries start at index `1`.

Internally, no dynamic storage is used.

Template Parameters

|                            |                                                 |
|----------------------------|-------------------------------------------------|
| <code>T<sub>-</sub></code> | Data type (double, float, complex<double>, ...) |
| <code>N<sub>-</sub></code> | Vector size                                     |

### 7.63.2 Constructor & Destructor Documentation

**LocalVect ( const Element \* *el*, const Vect< T<sub>-</sub> > & *v*, int *opt* = 0 )**

Constructor of an element vector from a global `Vect` instance.

The constructed vector has local numbering of nodes

Parameters

|    |            |                                                                                                                                                                                                                           |
|----|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>  | Pointer to <code>Element</code> to localize                                                                                                                                                                               |
| in | <i>v</i>   | Global vector to localize                                                                                                                                                                                                 |
| in | <i>opt</i> | Option for DOF treatment <ul style="list-style-type: none"> <li>• = 0, Normal case [Default]</li> <li>• Any other value : only one DOF is handled (Local vector has as dimension number of degrees of freedom)</li> </ul> |

**LocalVect ( const Side \* *sd*, const Vect< T<sub>-</sub> > & *v*, int *opt* = 0 )**

Constructor of a side vector from a global `Vect` instance.

The constructed vector has local numbering of nodes

Parameters

|    |            |                                                                                                                                                                                                                           |
|----|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>sd</i>  | Pointer to <a href="#">Side</a> to localize                                                                                                                                                                               |
| in | <i>v</i>   | Global vector to localize                                                                                                                                                                                                 |
| in | <i>opt</i> | Option for DOF treatment <ul style="list-style-type: none"> <li>• = 0, Normal case [Default]</li> <li>• Any other value : only one DOF is handled (Local vector has as dimension number of degrees of freedom)</li> </ul> |

### 7.63.3 Member Function Documentation

**void getLocal ( const Element &el, const Vect< T\_ > &v, int type )**

Localize an element vector from a global [Vect](#) instance.

The constructed vector has local numbering of nodes This function is called by the constructor-  
: **LocalVect**(const Element \*el, const Vect<T\_> &v)

Parameters

|    |             |                                                                                                             |
|----|-------------|-------------------------------------------------------------------------------------------------------------|
| in | <i>el</i>   | Pointer to <a href="#">Element</a> to localize                                                              |
| in | <i>v</i>    | Global vector to localize                                                                                   |
| in | <i>type</i> | Type of element. This is to be chosen among enumerated values: LINE2, TRIANG3, QUAD4, TETRA4, HEXA8, PENTA6 |

**void Localize ( const Element \*el, const Vect< T\_ > &v, size\_t k = 0 )**

Localize an element vector from a global [Vect](#) instance.

The constructed vector has local numbering of nodes This function is called by the constructor-  
: **LocalVect**(const Element \*el, const Vect<T\_> &v)

Parameters

|    |           |                                                                            |
|----|-----------|----------------------------------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Side</a> to localize                                |
| in | <i>v</i>  | Global vector to localize                                                  |
| in | <i>k</i>  | Degree of freedom to localize [Default: All degrees of freedom are stored] |

**void Localize ( const Side \*sd, const Vect< T\_ > &v, size\_t k = 0 )**

Localize a side vector from a global [Vect](#) instance.

The constructed vector has local numbering of nodes This function is called by the constructor-  
: **LocalVect**(const Side \*sd, const Vect<T\_> &v)

Parameters

|    |           |                                                                            |
|----|-----------|----------------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to <a href="#">Side</a> to localize                                |
| in | <i>v</i>  | Global vector to localize                                                  |
| in | <i>k</i>  | Degree of freedom to localize [Default: All degrees of freedom are stored] |

**T\_& operator[] ( size\_t i )**

Operator [] (Non constant version).

v[i] starts at v[0] to v[size()-1]

**T\_ operator[] ( size\_t i ) const**

Operator [] (Constant version).  
v[i] starts at v[0] to v[size()-1]

**T\_& operator() ( size\_t i )**

Operator () (Non constant version).  
v(i) starts at v(1) to v(size()). v(i) is the same element as v[i-1]

**T\_ operator() ( size\_t i ) const**

Operator () (Constant version).  
v(i) starts at v(1) to v(size()) v(i) is the same element as v[i-1]

**LocalVect< T\_, N\_ > & operator= ( const LocalVect< T\_, N\_ > & v )**

Operator =  
Copy a [LocalVect](#) instance to the current one

**LocalVect< T\_, N\_ > & operator= ( const T\_ & x )**

Operator =  
Assign value x to all vector entries

**LocalVect< T\_, N\_ > & operator+= ( const LocalVect< T\_, N\_ > & v )**

Operator +=  
Add vector v to this instance

**LocalVect< T\_, N\_ > & operator+= ( const T\_ & a )**

Operator +=  
Add constant a to vector entries

**LocalVect< T\_, N\_ > & operator-= ( const LocalVect< T\_, N\_ > & v )**

Operator -=  
Subtract vector v from this instance

**LocalVect< T\_, N\_ > & operator-= ( const T\_ & a )**

Operator -=  
Subtract constant a from vector entries

**LocalVect< T\_, N\_ > & operator\*= ( const T\_ & a )**

Operator \*=  
Multiply vector by constant a

**LocalVect< T\_, N\_ > & operator/= ( const T\_ & a )**

Operator /=  
Divide vector by constant a

**T\_ operator, ( const LocalVect< T\_, N\_ > & v ) const**

Return Dot (scalar) product of two vectors.

A typical use of this operator is `double a = (v,w)` where `v` and `w` are 2 instances of `LocalVect<double,n>`

Parameters

|    |                |                                                                             |
|----|----------------|-----------------------------------------------------------------------------|
| in | <code>v</code> | <code>LocalVect</code> instance by which the current instance is multiplied |
|----|----------------|-----------------------------------------------------------------------------|

## 7.64 Material Class Reference

To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members.

### Public Member Functions

- `Material ()`  
*Default constructor.*
- `Material (const Material &m)`  
*Copy constructor.*
- `~Material ()`  
*Destructor.*
- `int set (int m, const string &name)`  
*Associate to material code number `n` the material named `name`*
- `string getName (int m) const`  
*Return material name for material with code `m`*
- `int getCode (size_t i) const`  
*Return material code for `i`-th material.*
- `size_t getNbMat () const`  
*Return Number of read materials.*
- `void setCode (int m)`  
*Associate code `m` to current material.*
- `int check (int c)`
- `real_t Density ()`  
*Return constant density.*
- `real_t Density (const Point< real_t > &x, real_t t)`  
*Return density at point `x` and time `t`*
- `real_t SpecificHeat ()`  
*Return constant specific heat.*
- `real_t SpecificHeat (const Point< real_t > &x, real_t t)`  
*Return specific heat at point `x` and time `t`*
- `real_t ThermalConductivity ()`  
*Return constant thermal conductivity.*
- `real_t ThermalConductivity (const Point< real_t > &x, real_t t)`  
*Return thermal conductivity at point `x` and time `t`*
- `real_t MeltingTemperature ()`  
*Return constant melting temperature.*
- `real_t MeltingTemperature (const Point< real_t > &x, real_t t)`

- Return melting temperature at point  $x$  and time  $t$*

  - [real.t EvaporationTemperature](#) ()

*Return constant evaporation temperature.*

  - [real.t EvaporationTemperature](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return evaporation temperature at point  $x$  and time  $t$*

  - [real.t ThermalExpansion](#) ()

*Return constant thermal expansion coefficient.*

  - [real.t ThermalExpansion](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return thermal expansion coefficient at point  $x$  and time  $t$*

  - [real.t LatentHeatForMelting](#) ()

*Return constant latent heat for melting.*

  - [real.t LatentHeatForMelting](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return latent heat for melting at point  $x$  and time  $t$*

  - [real.t LatentHeatForEvaporation](#) ()

*Return constant latent heat for evaporation.*

  - [real.t LatentHeatForEvaporation](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return latent heat for evaporation at point  $x$  and time  $t$*

  - [real.t DielectricConstant](#) ()

*Return constant dielectric constant.*

  - [real.t DielectricConstant](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return dielectric constant at point  $x$  and time  $t$*

  - [real.t ElectricConductivity](#) ()

*Return constant electric conductivity.*

  - [real.t ElectricConductivity](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return electric conductivity at point  $x$  and time  $t$*

  - [real.t ElectricResistivity](#) ()

*Return constant electric resistivity.*

  - [real.t ElectricResistivity](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return electric resistivity at point  $x$  and time  $t$*

  - [real.t MagneticPermeability](#) ()

*Return constant magnetic permeability.*

  - [real.t MagneticPermeability](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return magnetic permeability at point  $x$  and time  $t$*

  - [real.t Viscosity](#) ()

*Return constant viscosity.*

  - [real.t Viscosity](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return viscosity at point  $x$  and time  $t$*

  - [real.t YoungModulus](#) ()

*Return constant Young modulus.*

  - [real.t YoungModulus](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return Young modulus at point  $x$  and time  $t$*

  - [real.t PoissonRatio](#) ()

*Return constant Poisson ratio.*

  - [real.t PoissonRatio](#) (const [Point](#)< [real.t](#) > & $x$ , [real.t](#)  $t$ )

*Return Poisson ratio at point  $x$  and time  $t$*

  - [real.t Property](#) (int  $i$ )



*Return constant  $i$ -th property.*

- **real.t Property** (int  $i$ , const **Point**< **real.t** > & $x$ , **real.t**  $t$ )

*Return  $i$ -th property at point  $x$  and time  $t$*

- **Material** & **operator=** (const **Material** & $m$ )

*Operator =.*

### 7.64.1 Detailed Description

To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members.

### 7.64.2 Constructor & Destructor Documentation

**Material** ( )

Default constructor.

It initializes the class and searches for the path where are material data files.

### 7.64.3 Member Function Documentation

**int set** ( int  $m$ , const string &  $name$  )

Associate to material code number  $n$  the material named  $name$

Returns

Number of materials

**string getName** ( int  $m$  ) const

Return material name for material with code  $m$

If such a material is not found, return a blank string.

**int check** ( int  $c$  )

Check if material code  $c$  is present.

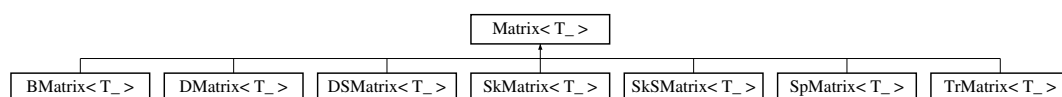
Returns

0 if succeeded, 1 if not.

## 7.65 Matrix< T\_ > Class Template Reference

Virtual class to handle matrices for all storage formats.

Inheritance diagram for Matrix< T\_ >:



## Public Member Functions

- **Matrix** ()  
*Default constructor.*
- **Matrix** (const **Matrix**< T\_ > &m)  
*Copy Constructor.*
- virtual **~Matrix** ()  
*Destructor.*
- size\_t **getNbRows** () const  
*Return number of rows.*
- size\_t **getNbColumns** () const  
*Return number of columns.*
- void **setPenal** (real\_t p)  
*Set Penalty Parameter (For boundary condition prescription).*
- void **setDiagonal** ()  
*Set the matrix as diagonal.*
- T\_ **getDiag** (size\_t k) const  
*Return k-th diagonal entry of matrix.*
- size\_t **size** () const  
*Return matrix dimension (Number of rows and columns).*
- virtual void **MultAdd** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const =0  
*Multiply matrix by vector x and add to y*
- virtual void **MultAdd** (T\_ a, const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const =0  
*Multiply matrix by vector a\*x and add to y*
- virtual void **Mult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const =0  
*Multiply matrix by vector x and save in y*
- virtual void **TMult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const =0  
*Multiply transpose of matrix by vector x and save in y*
- virtual void **Axpy** (T\_ a, const **Matrix**< T\_ > \*x)=0  
*Add to matrix the product of a matrix by a scalar.*
- void **setDiagonal** (**Mesh** &mesh)  
*Initialize matrix storage in the case where only diagonal terms are stored.*
- void **Assembly** (const **Element** &el, T\_ \*a)  
*Assembly of element matrix into global matrix.*
- void **Assembly** (const **Element** &el, const **DMatrix**< T\_ > &a)  
*Assembly of element matrix into global matrix.*
- void **Assembly** (const **Side** &sd, T\_ \*a)  
*Assembly of side matrix into global matrix.*
- void **Assembly** (const **Side** &sd, const **DMatrix**< T\_ > &a)  
*Assembly of side matrix into global matrix.*
- void **Prescribe** (**Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.*
- void **Prescribe** (int dof, int code, **Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- void **Prescribe** (**Vect**< T\_ > &b, int flag=0)  
*Impose by a penalty method a homogeneous (=0) essential boundary condition.*

- void **Prescribe** (size\_t dof, **Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- void **PrescribeSide** ()  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- virtual void **add** (size\_t i, size\_t j, const T\_ &val)=0  
*Add val to entry (i, j).*
- virtual int **Factor** ()=0  
*Factorize matrix. Available only if the storage class enables it.*
- virtual int **solve** (**Vect**< T\_ > &b)=0  
*Solve the linear system by a direct method.*
- int **solve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve system with factorized matrix (forward and back substitution).*
- int **FactorAndSolve** (**Vect**< T\_ > &b)  
*Factorize matrix and solve the linear system.*
- int **FactorAndSolve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Factorize matrix and solve the linear system.*
- size\_t **getLength** () const  
*Return number of stored terms in matrix.*
- int **isDiagonal** () const  
*Say if matrix is diagonal or not.*
- int **isFactorized** () const  
*Say if matrix is factorized or not.*
- virtual size\_t **getColInd** (size\_t i) const  
*Return Column index for column i (See the description for class [SpMatrix](#)).*
- virtual size\_t **getRowPtr** (size\_t i) const  
*Return Row pointer for row i (See the description for class [SpMatrix](#)).*
- virtual void **set** (size\_t i, size\_t j, const T\_ &val)=0  
*Assign a value to an entry of the matrix.*
- virtual T\_ & **operator()** (size\_t i, size\_t j)=0  
*Operator () (Non constant version).*
- virtual T\_ **operator()** (size\_t i, size\_t j) const =0  
*Operator () (Non constant version).*
- T\_ **operator()** (size\_t i) const  
*Operator () with one argument (Constant version).*
- T\_ & **operator()** (size\_t i)  
*Operator () with one argument (Non Constant version).*
- T\_ & **operator[]** (size\_t k)  
*Operator [] (Non constant version).*
- T\_ **operator[]** (size\_t k) const  
*Operator [] (Constant version).*
- **Matrix** & **operator=** (**Matrix**< T\_ > &m)  
*Operator =.*
- **Matrix** & **operator+=** (const **Matrix**< T\_ > &m)  
*Operator +=.*
- **Matrix** & **operator-=** (const **Matrix**< T\_ > &m)  
*Operator -=.*

- **Matrix** & **operator=** (const T\_ &x)  
*Operator =.*
- **Matrix** & **operator\*=** (const T\_ &x)  
*Operator \*.*
- **Matrix** & **operator+=** (const T\_ &x)  
*Operator +=.*
- **Matrix** & **operator-=** (const T\_ &x)  
*Operator -=.*
- virtual T\_ **get** (size\_t i, size\_t j) const =0  
*Return entry (i, j) of matrix if this one is stored, 0 else.*

### 7.65.1 Detailed Description

**template<class T\_>class OFELI::Matrix< T\_ >**

Virtual class to handle matrices for all storage formats.

Template Parameters

|      |                                                 |
|------|-------------------------------------------------|
| <T_> | Data type (real_t, float, complex<real_t>, ...) |
|------|-------------------------------------------------|

### 7.65.2 Constructor & Destructor Documentation

**Matrix ( )**

Default constructor.

Initializes a zero-size matrix.

### 7.65.3 Member Function Documentation

**T\_ getDiag ( size\_t k ) const**

Return k-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**virtual void Apy ( T\_ a, const Matrix< T\_ > \* x )** [pure virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |          |                                                                          |
|----|----------|--------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                    |
| in | <i>x</i> | Matrix by which a is multiplied. The result is added to current instance |

Implemented in [SpMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< T\\_ >](#).

**void setDiagonal ( Mesh & mesh )**

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**void Assembly ( const Element & el, T\_ \* a )**

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )**

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_ \* *a* )**

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )**

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( int dof, int code, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )**

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |      |                                                                                                                                              |
|--------|------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | dof  | Degree of freedom for which a boundary condition is to be enforced                                                                           |
| in     | code | Code for which a boundary condition is to be enforced                                                                                        |
| in,out | b    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | u    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | flag | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & b, int flag = 0 )**

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |      |                                                                                                                                              |
|--------|------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | b    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | flag | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )**

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|        |      |                                                                                                                                              |
|--------|------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | dof  | Label of the concerned degree of freedom (DOF).                                                                                              |
| in,out | b    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | u    | <a href="#">Vect</a> instance that conatins imposed valued at DOFs where they are to be imposed.                                             |
| in     | flag | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )**

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**virtual int solve ( Vect< T\_ > & b )** [pure virtual]

Solve the linear system by a direct method.

This is available only if the storage class enables it and if matrix has been primarily factorized (See **isFactorized**).

Implemented in [SpMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [BMatrix< T\\_ >](#), and [TrMatrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve system with factorized matrix (forward and back substitution).

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

-

- 0 if solution was normally performed
  - *n* if the *n*-th pivot is null
- Solution is performed only is factorization has previously been invoked.

**int FactorAndSolve ( Vect< T\_ > & b )**

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |          |                                                                                             |
|--------|----------|---------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|--------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- *n* if the *n*-th pivot is nul

**int isFactorized ( ) const**

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**virtual void set ( size\_t i, size\_t j, const T\_ & val )** [pure virtual]

Assign a value to an entry of the matrix.

Parameters

|    |            |                 |
|----|------------|-----------------|
| in | <i>i</i>   | Row index       |
| in | <i>j</i>   | Column index    |
| in | <i>val</i> | Value to assign |

Implemented in [SpMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), [BMatrix< T\\_ >](#), and [DSMatrix< T\\_ >](#).

**virtual T\_ & operator() ( size\_t i, size\_t j )** [pure virtual]

Operator () (Non constant version).

Returns the (i, j) entry of the matrix.

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implemented in [SpMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), [BMatrix< T\\_ >](#), and [DSMatrix< T\\_ >](#).

**virtual T\_ operator() ( size\_t i, size\_t j ) const** [pure virtual]

Operator () (Non constant version).

Returns the (i, j) entry of the matrix.

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implemented in [SpMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), [BMatrix< T\\_ >](#), and [DSMatrix< T\\_ >](#).

**T\_ operator() ( size\_t i ) const**

Operator () with one argument (Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |          |             |
|----|----------|-------------|
| in | <i>i</i> | entry index |
|----|----------|-------------|

**T\_ & operator() ( size\_t i )**

Operator () with one argument (Non Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.



Parameters

|                 |                |             |
|-----------------|----------------|-------------|
| <code>in</code> | <code>i</code> | entry index |
|-----------------|----------------|-------------|

**`T_& operator[] ( size_t k )`**

Operator [] (Non constant version).

Returns k-th stored element in matrix Index k starts at 0.

**`T_ operator[] ( size_t k ) const`**

Operator [] (Constant version).

Returns k-th stored element in matrix Index k starts at 0.

**`Matrix& operator= ( Matrix< T_ > & m )`**

Operator =.

Copy matrix m to current matrix instance.

**`Matrix& operator+= ( const Matrix< T_ > & m )`**

Operator +=.

Add matrix m to current matrix instance.

**`Matrix& operator-= ( const Matrix< T_ > & m )`**

Operator -=.

Subtract matrix m from current matrix instance.

**`Matrix& operator= ( const T_ & x )`**

Operator =.

Assign constant value x to all matrix entries.

**`Matrix& operator*= ( const T_ & x )`**

Operator \*.

Premultiply matrix entries by constant value x

**`Matrix& operator+= ( const T_ & x )`**

Operator +=.

Add constant value x to all matrix entries.

**`Matrix& operator-= ( const T_ & x )`**

Operator -=.

Subtract constant value x from all matrix entries.

## 7.66 Mesh Class Reference

To store and manipulate finite element meshes.

## Public Member Functions

- [Mesh](#) ()  
*Default constructor (Empty mesh)*
- [Mesh](#) (const string &file, bool bc=false, int opt=NODE\_DOF)  
*Constructor using a mesh file.*
- [Mesh](#) (real\_t L, size\_t nb\_el, size\_t p=1, size\_t nb\_dof=1)  
*Constructor for a 1-D mesh. The domain is the interval [0,L].*
- [Mesh](#) (const [Grid](#) &g, int opt=QUADRILATERAL)  
*Constructor for a uniform finite difference grid given by and instance of class [Grid](#).*
- [Mesh](#) (const [Grid](#) &g, int shape, int opt)  
*Constructor of dual mesh for a uniform finite difference grid given by and instance of class [Grid](#).*
- [Mesh](#) (real\_t xL, real\_t yL, size\_t nx, size\_t ny, int c1, int c2, int c3, int c4, int opt=0)  
*Constructor for a uniform finite difference grid.*
- [Mesh](#) (const [Mesh](#) &m, const [Point](#)< real\_t > &x\_bl, const [Point](#)< real\_t > &x\_tr)  
*Constructor that extracts the mesh of a rectangular region from an initial mesh.*
- [Mesh](#) (const [Mesh](#) &mesh, int opt, size\_t dof1, size\_t dof2, bool bc=false)  
*Constructor that copies the input mesh and selects given degrees of freedom.*
- [Mesh](#) (const [Mesh](#) &ms)  
*Copy Constructor.*
- [~Mesh](#) ()  
*Destructor.*
- void [setDim](#) (size\_t dim)  
*Define space dimension. Normally, between 1 and 3.*
- void [setVerbose](#) (int verb)  
*Define Verbose Parameter. Controls output details.*
- void [Add](#) ([Node](#) \*nd)  
*Add a node to mesh.*
- void [Add](#) ([Element](#) \*el)  
*Add an element to mesh.*
- void [Add](#) ([Side](#) \*sd)  
*Add a side to mesh.*
- void [Add](#) ([Edge](#) \*ed)  
*Add an edge to mesh.*
- [Mesh](#) & operator\*= (real\_t a)  
*Operator \*=*
- void [get](#) (const string &mesh\_file)  
*Read mesh data in file.*
- void [get](#) (const string &mesh\_file, int ff, int nb\_dof=1)  
*Read mesh data in file with giving its format.*
- void [setDOFSupport](#) (int opt, int nb\_nodes=1)  
*Define supports of degrees of freedom.*
- void [setNbDOFPerNode](#) (size\_t nb\_dof=1)  
*Define number of degrees of freedom for each node.*
- void [setPointInDomain](#) ([Point](#)< real\_t > x)  
*Define a point in the domain. This function makes sense only if boundary mesh is given without internal mesh (Case of Boundary Elements)*

- void `removeImposedDOF` ()  
*Eliminate equations corresponding to imposed DOF.*
- size\_t `NumberEquations` (size\_t dof=0)  
*Renumber Equations.*
- size\_t `NumberEquations` (size\_t dof, int c)  
*Renumber Equations.*
- int `getAllSides` (int opt=0)  
*Determine all mesh sides.*
- size\_t `getNbSideNodes` () const  
*Return the number of nodes on each side.*
- size\_t `getNbElementNodes` () const  
*Return the number of nodes in each element.*
- int `getBoundarySides` ()  
*Determine all boundary sides.*
- int `createBoundarySideList` ()  
*Create list of boundary sides.*
- int `getBoundaryNodes` ()  
*Determine all boundary nodes.*
- int `createInternalSideList` ()  
*Create list of internal sides (not on the boundary).*
- int `getAllEdges` ()  
*Determine all edges.*
- void `getNodeNeighborElements` ()  
*Create node neighboring elements.*
- void `getElementNeighborElements` ()  
*Create element neighboring elements.*
- void `setMaterial` (int code, const string &mname)  
*Associate material to code of element.*
- void `Reorder` (size\_t m=GRAPH\_MEMORY)  
*Renumber mesh nodes according to reverse Cuthill Mc Kee algorithm.*
- void `Add` (size\_t num, real\_t \*x)  
*Add a node by giving its label and an array containing its coordinates.*
- void `DeleteNode` (size\_t label)  
*Remove a node given by its label.*
- void `DeleteElement` (size\_t label)  
*Remove an element given by its label.*
- void `DeleteSide` (size\_t label)  
*Remove a side given by its label.*
- void `Delete` (Node \*nd)  
*Remove a node given by its pointer.*
- void `Delete` (Element \*el)  
*Remove a node given by its pointer.*
- void `Delete` (Side \*sd)  
*Remove a side given by its pointer.*
- void `Delete` (Edge \*ed)  
*Remove an edge given by its pointer.*

- void **RenumberNode** (size\_t n1, size\_t n2)  
*Renumber a node.*
- void **RenumberElement** (size\_t n1, size\_t n2)  
*Renumber an element.*
- void **RenumberSide** (size\_t n1, size\_t n2)  
*Renumber a side.*
- void **RenumberEdge** (size\_t n1, size\_t n2)  
*Renumber an edge.*
- void **setNodeView** (size\_t n1, size\_t n2)  
*Set viewing window for nodes.*
- void **setElementView** (size\_t n1, size\_t n2)  
*Set viewing window for elements.*
- void **setSideView** (size\_t n1, size\_t n2)  
*Set viewing window for sides.*
- void **setEdgeView** (size\_t n1, size\_t n2)  
*Set viewing window for edges.*
- void **setList** (const std::vector< **Node** \* > &n1)  
*Initialize list of mesh nodes using the input vector.*
- void **setList** (const std::vector< **Element** \* > &el)  
*Initialize list of mesh elements using the input vector.*
- void **setList** (const std::vector< **Side** \* > &sl)  
*Initialize list of mesh sides using the input vector.*
- void **Rescale** (real\_t sx, real\_t sy=0., real\_t sz=0.)  
*Rescale mesh by multiplying node coordinates by constants.*
- int **getVerbose** () const  
*Return Verbose Parameter.*
- size\_t **getDim** () const  
*Return space dimension.*
- size\_t **getNbNodes** () const  
*Return number of nodes.*
- size\_t **getNbMarkedNodes** () const  
*Return number of marked nodes.*
- size\_t **getNbVertices** () const  
*Return number of vertices.*
- size\_t **getNbDOF** () const  
*Return total number of degrees of freedom (DOF)*
- size\_t **getNbEq** () const  
*Return number of equations.*
- size\_t **getNbEq** (int i) const  
*Return number of equations for the i-th set of degrees of freedom.*
- size\_t **getNbElements** () const  
*Return number of elements.*
- size\_t **getNbSides** () const  
*Return number of sides.*
- size\_t **getNbEdges** () const  
*Return number of sides.*

- `size_t getNbBoundarySides () const`  
*Return number of boundary sides.*
- `size_t getNbInternalSides () const`  
*Return number of internal sides.*
- `size_t getNbMat () const`  
*Return number of materials.*
- `void AddMidNodes (int g=0)`  
*Add mid-side nodes.*
- `Point< real_t > getMaxCoord () const`  
*Return maximum coordinates of nodes.*
- `Point< real_t > getMinCoord () const`  
*Return minimum coordinates of nodes.*
- `void set (Node *nd)`  
*Replace node in the mesh.*
- `void set (Element *el)`  
*Replace element in the mesh.*
- `void set (Side *sd)`  
*Choose side in the mesh.*
- `bool NodesAreDOF () const`  
*Return information about DOF type.*
- `bool SidesAreDOF () const`  
*Return information about DOF type.*
- `bool EdgesAreDOF () const`  
*Return information about DOF type.*
- `bool ElementsAreDOF () const`  
*Return information about DOF type.*
- `int getDOFSupport () const`  
*Return information on dof support Return an integer according to enumerated values: NODE\_DOF, ELEMENT\_DOF SIDE\_DOF.*
- `void put (const string &mesh_file) const`  
*Write mesh data on file.*
- `void save (const string &mesh_file) const`  
*Write mesh data on file in various formats.*
- `void Bput (const string &mesh_file) const`  
*Write mesh data on a binary file.*
- `bool withImposedDOF () const`  
*Return true if imposed DOF count in equations, false if not.*
- `bool isStructured () const`  
*Return true is mesh is structured, false if not.*
- `size_t getNodeNewLabel (size_t n) const`  
*Return new label of node of a renumbered node.*
- `void getList (vector< Node * > &nl) const`  
*Fill vector nl with list of pointers to nodes.*
- `void getList (vector< Element * > &el) const`  
*Fill vector el with list of pointers to elements.*
- `void getList (vector< Side * > &sl) const`  
*Fill vector sl with list of pointers to sides.*

- **Node** \* **getPtrNode** (size\_t i) const  
*Return pointer to node with label i.*
- **Node** & **getNode** (size\_t i) const  
*Return referenrece to node with label i*
- **Element** \* **getPtrElement** (size\_t i) const  
*Return pointer to element with label i*
- **Element** & **getElement** (size\_t i) const  
*Return reference to element with label i*
- **Side** \* **getPtrSide** (size\_t i) const  
*Return pointer to side with label i*
- **Side** & **getSide** (size\_t i) const  
*Return reference to side with label i*
- **Edge** \* **getPtrEdge** (size\_t i) const  
*Return pointer to edge with label i*
- **Edge** & **getEdge** (size\_t i) const  
*Return reference to edge with label i*
- size\_t **getNodeLabel** (size\_t i) const  
*Return label of i-th node.*
- size\_t **getElementLabel** (size\_t i) const  
*Return label of i-th element.*
- size\_t **getSideLabel** (size\_t i) const  
*Return label of i-th side.*
- size\_t **getEdgeLabel** (size\_t i) const  
*Return label of i-th edge.*
- void **topNode** () const  
*Reset list of nodes at its top position (Non constant version)*
- void **topBoundaryNode** () const  
*Reset list of boundary nodes at its top position (Non constant version)*
- void **topMarkedNode** () const  
*Reset list of marked nodes at its top position (Non constant version)*
- void **topElement** () const  
*Reset list of elements at its top position (Non constant version)*
- void **topSide** () const  
*Reset list of sides at its top position (Non constant version)*
- void **topBoundarySide** () const  
*Reset list of boundary sides at its top position (Non constant version)*
- void **topInternalSide** () const  
*Reset list of intrenal sides at its top position (Non constant version)*
- void **topEdge** () const  
*Reset list of edges at its top position (Non constant version)*
- void **topBoundaryEdge** () const  
*Reset list of boundary edges at its top position (Non constant version)*
- **Node** \* **getNode** () const  
*Return pointer to current node and move to next one (Non constant version)*
- **Node** \* **getBoundaryNode** () const  
*Return pointer to current boundary node and move to next one (Non constant version)*

- `Node * getMarkedNode () const`  
*Return pointer to current marked node and move to next one (Non constant version)*
- `Element * getElement () const`  
*Return pointer to current element and move to next one (Non constant version)*
- `Element * getActiveElement () const`  
*Return pointer to current element and move to next one (Non constant version)*
- `Side * getSide () const`  
*Return pointer to current side and move to next one (Non constant version)*
- `Side * getBoundarySide () const`  
*Return pointer to current boundary side and move to next one (Non constant version)*
- `Side * getInternalSide () const`  
*Return pointer to current internal side and move to next one (Non constant version)*
- `Edge * getEdge () const`  
*Return pointer to current edge and move to next one (Non constant version)*
- `Edge * getBoundaryEdge () const`  
*Return pointer to current boundary edge and move to next one (Non constant version)*
- `int getShape () const`  
*Determine shape of elements Return Shape index (see enum ElementShape) if all elements have the same shape, 0 if not.*
- `Element * operator() (size_t i) const`  
*Operator () : Return pointer to i-th element.*
- `Node * operator[] (size_t i) const`  
*Operator [] : Return pointer to i-th node.*
- `size_t operator() (size_t i, size_t n) const`  
*Operator () : Return pointer to i-th node of n-th element.*
- `Mesh & operator= (Mesh &ms)`  
*Operator = : Assign a Mesh instance.*

## Friends

- `void Refine (Mesh &in_mesh, Mesh &out_mesh)`  
*Refine mesh. Subdivide each triangle into 4 subtriangles. This member function is valid for 2-D triangular meshes only.*

### 7.66.1 Detailed Description

To store and manipulate finite element meshes.

Class `Mesh` enables defining as an object a finite element mesh. A finite element mesh is characterized by its nodes, elements and sides. Each of these types of data constitutes a class in the `OFELI` library.

The standard procedure to introduce the finite element mesh is to provide an input file containing its data. For this, we have defined our own mesh data file (following the XML syntax). Of course, a developer can write his own function to read his finite element mesh file using the methods in `Mesh`.

### 7.66.2 Constructor & Destructor Documentation

`Mesh ( const string & file, bool bc = false, int opt = NODE_DOF )`

Constructor using a mesh file.

Parameters

|    |             |                                                                                                                                                                               |
|----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>file</i> | File containing mesh data                                                                                                                                                     |
| in | <i>bc</i>   | Flag to remove (true) or not (false) imposed Degrees of Freedom [default: false]                                                                                              |
| in | <i>opt</i>  | Type of DOF support: To choose among enumerated values NOD-E_DOF, SIDE_DOF or ELEMENT_DOF.<br>Say if degrees of freedom (unknowns) are supported by nodes, sides or elements. |

**Mesh ( real.t *L*, size.t *nb\_el*, size.t *p* = 1, size.t *nb\_dof* = 1 )**

Constructor for a 1-D mesh. The domain is the interval [0,L].

Parameters

|    |               |                                                          |
|----|---------------|----------------------------------------------------------|
| in | <i>L</i>      | Length of the interval                                   |
| in | <i>nb_el</i>  | Number of elements to generate                           |
| in | <i>p</i>      | Degree of finite element polynomial (Default = 1)        |
| in | <i>nb_dof</i> | Number of degrees of freedom for each node (Default = 1) |

**Mesh ( const Grid & *g*, int *opt* = QUADRILATERAL )**

Constructor for a uniform finite difference grid given by and instance of class [Grid](#).

Parameters

|    |            |                                                                                                                                                                                                                         |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>g</i>   | <a href="#">Grid</a> instance                                                                                                                                                                                           |
| in | <i>opt</i> | Optional value to say which type of elements to generate <ul style="list-style-type: none"> <li>• TRIANGLE: Mesh elements are triangles</li> <li>• QUADRILATERAL: Mesh elements are quadrilaterals [default]</li> </ul> |

**Mesh ( const Grid & *g*, int *shape*, int *opt* )**

Constructor of dual mesh for a uniform finite difference grid given by and instance of class [Grid](#).

Parameters

|    |              |                                                                                                                                                                                                                |
|----|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>g</i>     | <a href="#">Grid</a> instance                                                                                                                                                                                  |
| in | <i>shape</i> | Value to say which type of elements to generate <ul style="list-style-type: none"> <li>• TRIANGLE: Mesh elements are triangles</li> <li>• QUADRILATERAL: Mesh elements are quadrilaterals [default]</li> </ul> |



|                 |                  |                                                                                                                                  |
|-----------------|------------------|----------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>opt</code> | This argument can take any value. It is here only to distinguish from the other constructor using <a href="#">Grid</a> instance. |
|-----------------|------------------|----------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This constructor is to be used to obtain a dual mesh from a structured grid. It is mainly useful if a cell centered finite volume method is used.

**Mesh ( `real.t xL`, `real.t yL`, `size.t nx`, `size.t ny`, `int c1`, `int c2`, `int c3`, `int c4`, `int opt = 0` )**

Constructor for a uniform finite difference grid.

The domain is the rectangle (0,Lx)x(0,Ly)

Parameters

|                 |                  |                                                                                                                                                                                |
|-----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>xL</code>  | Length in the x-direction                                                                                                                                                      |
| <code>in</code> | <code>yL</code>  | Length in the y-direction                                                                                                                                                      |
| <code>in</code> | <code>nx</code>  | Number of subintervals on the x-axis                                                                                                                                           |
| <code>in</code> | <code>ny</code>  | Number of subintervals on the y-axis                                                                                                                                           |
| <code>in</code> | <code>c1</code>  | Code for nodes generated on the line y=0                                                                                                                                       |
| <code>in</code> | <code>c2</code>  | Code for nodes generated on the line x=Lx                                                                                                                                      |
| <code>in</code> | <code>c3</code>  | Code for nodes generated on the line y=Ly                                                                                                                                      |
| <code>in</code> | <code>c4</code>  | Code for nodes generated on the line x=0                                                                                                                                       |
| <code>in</code> | <code>opt</code> | Flag to generate elements as well (if not zero) [Default: 0]. If the flag is not 0, it can take one of the enumerated values: TRIANGLE or QUADRILATERAL, with obvious meaning. |

**Mesh ( `const Mesh & m`, `const Point< real.t > & x_bl`, `const Point< real.t > & x_tr` )**

Constructor that extracts the mesh of a rectangular region from an initial mesh.

This constructor is useful for zooming purposes for instance.

Parameters

|                 |                   |                                                   |
|-----------------|-------------------|---------------------------------------------------|
| <code>in</code> | <code>m</code>    | Initial mesh from which the submesh is extracted  |
| <code>in</code> | <code>x_bl</code> | Coordinate of bottom left vertex of the rectangle |
| <code>in</code> | <code>x_tr</code> | Coordinate of top right vertex of the rectangle   |

**Mesh ( `const Mesh & mesh`, `int opt`, `size.t dof1`, `size.t dof2`, `bool bc = false` )**

Constructor that copies the input mesh and selects given degrees of freedom.

This constructor is to be used for coupled problems where each subproblem uses a choice of degrees of freedom.

Parameters

|                 |                   |                                                                                            |
|-----------------|-------------------|--------------------------------------------------------------------------------------------|
| <code>in</code> | <code>mesh</code> | Initial mesh from which the submesh is extracted                                           |
| <code>in</code> | <code>opt</code>  | Type of DOF support: To choose among enumerated values NOD-E_DOF, SIDE_DOF or ELEMENT_DOF. |
| <code>in</code> | <code>dof1</code> | Label of first degree of freedom to select to the output mesh                              |
| <code>in</code> | <code>dof2</code> | Label of last degree of freedom to select to the output mesh                               |
| <code>in</code> | <code>bc</code>   | Flag to remove (true) or not (false) imposed Degrees of Freedom [Default: false]           |

**Mesh ( const Mesh & *ms* )**

Copy Constructor.

Parameters

|           |           |                                       |
|-----------|-----------|---------------------------------------|
| <i>in</i> | <i>ms</i> | <a href="#">Mesh</a> instance to copy |
|-----------|-----------|---------------------------------------|

### 7.66.3 Member Function Documentation

**void setDim ( *size\_t dim* )**

Define space dimension. Normally, between 1 and 3.

Parameters

|           |            |                                                  |
|-----------|------------|--------------------------------------------------|
| <i>in</i> | <i>dim</i> | Space dimension to set (must be between 1 and 3) |
|-----------|------------|--------------------------------------------------|

**void setVerbose ( *int verb* )**

Define Verbose Parameter. Controls output details.

Parameters

|           |             |                                                |
|-----------|-------------|------------------------------------------------|
| <i>in</i> | <i>verb</i> | verbosity parameter (Must be between 0 and 10) |
|-----------|-------------|------------------------------------------------|

**void Add ( *Node \* nd* )**

Add a node to mesh.

Parameters

|           |           |                                        |
|-----------|-----------|----------------------------------------|
| <i>in</i> | <i>nd</i> | Pointer to <a href="#">Node</a> to add |
|-----------|-----------|----------------------------------------|

**void Add ( *Element \* el* )**

Add an element to mesh.

Parameters

|           |           |                                           |
|-----------|-----------|-------------------------------------------|
| <i>in</i> | <i>el</i> | Pointer to <a href="#">Element</a> to add |
|-----------|-----------|-------------------------------------------|

**void Add ( *Side \* sd* )**

Add a side to mesh.

Parameters

|           |           |                                        |
|-----------|-----------|----------------------------------------|
| <i>in</i> | <i>sd</i> | Pointer to <a href="#">Side</a> to add |
|-----------|-----------|----------------------------------------|

**void Add ( *Edge \* ed* )**

Add an edge to mesh.

Parameters

|           |           |                                        |
|-----------|-----------|----------------------------------------|
| <i>in</i> | <i>ed</i> | Pointer to <a href="#">Edge</a> to add |
|-----------|-----------|----------------------------------------|

**Mesh& operator\*= ( *real\_t a* )**

Operator \*=

Rescale mesh coordinates by multiplying by a factor

Parameters

|    |          |                      |
|----|----------|----------------------|
| in | <i>a</i> | Value to multiply by |
|----|----------|----------------------|

**void get ( const string & *mesh\_file* )**

Read mesh data in file.

[Mesh](#) file must be in [OFELI](#) format. See "File Formats" page

Parameters

|    |                  |                                |
|----|------------------|--------------------------------|
| in | <i>mesh_file</i> | <a href="#">Mesh</a> file name |
|----|------------------|--------------------------------|

**void get ( const string & *mesh\_file*, int *ff*, int *nb\_dof* = 1 )**

Read mesh data in file with giving its format.

File format can be chosen among a variety of choices. See "File Formats" page

Parameters

|    |                  |                                                                                                                            |
|----|------------------|----------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh_file</i> | <a href="#">Mesh</a> file name                                                                                             |
| in | <i>ff</i>        | File format: Integer to chose among enumerated values: OFELI_FF, GMSH, MATLAB, EASYMESH, GAMBIT, BAMG, NETGEN, TRIANGLE_FF |
| in | <i>nb_dof</i>    | Number of degrees of freedom per node (Default value: 1)                                                                   |

**void setDOFSupport ( int *opt*, int *nb\_nodes* = 1 )**

Define supports of degrees of freedom.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                      |
|----|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>opt</i>      | DOF type: <ul style="list-style-type: none"> <li>• NODE_DOF: Degrees of freedom are supported by nodes</li> <li>• SIDE_DOF: Degrees of freedom are supported by sides</li> <li>• EDGE_DOF: Degrees of freedom are supported by edges</li> <li>• ELEMENT_DOF: Degrees of freedom are supported by elements</li> </ul> |
| in | <i>nb_nodes</i> | Number of nodes on sides or elements (default=1). This parameter is useful only if dofs are supported by sides or elements                                                                                                                                                                                           |

Note

This member function creates all mesh sides if the option ELEMENT\_DOF or SIDE\_DOF is selected. So it not necessary to call [getAllSides\(\)](#) after

**void setNbDOFPerNode ( size\_t *nb\_dof* = 1 )**

Define number of degrees of freedom for each node.

## Parameters

|           |               |                                                                                 |
|-----------|---------------|---------------------------------------------------------------------------------|
| <b>in</b> | <i>nb_dof</i> | Number of degrees of freedom (unknowns) for each mesh node (Default value is 1) |
|-----------|---------------|---------------------------------------------------------------------------------|

## Note

This function first declares nodes as unknown supports, sets the number of degrees of freedom and rennumbers equations

**void setPointInDomain ( Point< real\_t > x )**

Define a point in the domain. This function makes sense only if boundary mesh is given without internal mesh (Case of Boundary Elements)

## Parameters

|           |          |                                |
|-----------|----------|--------------------------------|
| <b>in</b> | <i>x</i> | Coordinates of point to define |
|-----------|----------|--------------------------------|

**size\_t NumberEquations ( size\_t dof = 0 )**

Renummer Equations.

## Parameters

|           |            |                                                                                                                                         |
|-----------|------------|-----------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>dof</i> | Label of degree of freedom for which numbering is performed. Default value (0) means that all degrees of freedom are taken into account |
|-----------|------------|-----------------------------------------------------------------------------------------------------------------------------------------|

**size\_t NumberEquations ( size\_t dof, int c )**

Renummer Equations.

## Parameters

|           |            |                                                              |
|-----------|------------|--------------------------------------------------------------|
| <b>in</b> | <i>dof</i> | Label of degree of freedom for which numbering is performed. |
| <b>in</b> | <i>c</i>   | code for which degrees of freedom are enforced.              |

**int getAllSides ( int opt = 0 )**

Determine all mesh sides.

## Returns

Number of all sides.

**int getBoundarySides ( )**

Determine all boundary sides.

## Returns

Number of boundary sides.

**int createBoundarySideList ( )**

Create list of boundary sides.

This function is useful to loop over boundary sides without testing. Once this one is called, the function [getNbBoundarySides\(\)](#) is available. Moreover, looping over boundary sides is available via the member functions [topBoundarySide\(\)](#) and [getBoundarySide\(\)](#)

Returns

Number of boundary sides.

**int getBoundaryNodes ( )**

Determine all boundary nodes.

Returns

n Number of boundary nodes.

**int createInternalSideList ( )**

Create list of internal sides (not on the boundary).

This function is useful to loop over internal sides without testing. Once this one is called, the function [getNbInternalSides\(\)](#) is available. Moreover, looping over internal sides is available via the member functions [topInternalSide\(\)](#) and [getInternalSide\(\)](#)

Returns

n Number of internal sides.

**int getAllEdges ( )**

Determine all edges.

Returns

Number of all edges.

**void getNodeNeighborElements ( )**

Create node neighboring elements.

This function is generally useful when, for a numerical method, one looks for a given node to the list of elements that share this node. Once this function is invoked, one can retrieve the list of neighboring elements of any node ([Node::getNeigEl](#))

**void getElementNeighborElements ( )**

Create element neighboring elements.

This function creates for each element the list of elements that share a side with it. Once this function is invoked, one can retrieve the list of neighboring elements of any element ([Element::getNeighborElement](#))

**void setMaterial ( int code, const string & mname )**

Associate material to code of element.

Parameters

|    |              |                                                             |
|----|--------------|-------------------------------------------------------------|
| in | <i>code</i>  | <a href="#">Element</a> code for which material is assigned |
| in | <i>mname</i> | Name of material                                            |

**void Reorder ( size.t *m* = GRAPH\_MEMORY )**

Renummer mesh nodes according to reverse Cuthill Mc Kee algorithm.

Parameters

|    |          |                                                                                         |
|----|----------|-----------------------------------------------------------------------------------------|
| in | <i>m</i> | Memory size needed for matrix graph (default value is GRAPH_MEMORY, see OFELI_Config.h) |
|----|----------|-----------------------------------------------------------------------------------------|

**void Add ( size.t *num*, real.t \* *x* )**

Add a node by giving its label and an array containing its coordinates.

Parameters

|    |            |                             |
|----|------------|-----------------------------|
| in | <i>num</i> | Label of node to add        |
| in | <i>x</i>   | C-array of node coordinates |

**void DeleteNode ( size.t *label* )**

Remove a node given by its label.

This function does not release the space previously occupied

Parameters

|    |              |                         |
|----|--------------|-------------------------|
| in | <i>label</i> | Label of node to delete |
|----|--------------|-------------------------|

**void DeleteElement ( size.t *label* )**

Remove an element given by its label.

This function does not release the space previously occupied

Parameters

|    |              |                            |
|----|--------------|----------------------------|
| in | <i>label</i> | Label of element to delete |
|----|--------------|----------------------------|

**void DeleteSide ( size.t *label* )**

Remove a side given by its label.

This function does not release the space previously occupied

Parameters

|    |              |                         |
|----|--------------|-------------------------|
| in | <i>label</i> | Label of side to delete |
|----|--------------|-------------------------|

**void Delete ( Node \* *nd* )**

Remove a node given by its pointer.

This function does not release the space previously occupied

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <b>in</b> | <i>nd</i> | Pointer to node to delete |
|-----------|-----------|---------------------------|

**void Delete ( Element \* *el* )**

Remove a node given by its pointer.

This function does not release the space previously occupied

Parameters

|           |           |                              |
|-----------|-----------|------------------------------|
| <b>in</b> | <i>el</i> | Pointer to element to delete |
|-----------|-----------|------------------------------|

**void Delete ( Side \* *sd* )**

Remove a side given by its pointer.

This function does not release the space previously occupied

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <b>in</b> | <i>sd</i> | Pointer to side to delete |
|-----------|-----------|---------------------------|

**void Delete ( Edge \* *ed* )**

Remove an edge given by its pointer.

This function does not release the space previously occupied

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <b>in</b> | <i>ed</i> | Pointer to edge to delete |
|-----------|-----------|---------------------------|

**void RenumberNode ( size\_t *n1*, size\_t *n2* )**

Renumber a node.

Parameters

|           |           |           |
|-----------|-----------|-----------|
| <b>in</b> | <i>n1</i> | Old label |
| <b>in</b> | <i>n2</i> | New label |

**void RenumberElement ( size\_t *n1*, size\_t *n2* )**

Renumber an element.

Parameters

|           |           |           |
|-----------|-----------|-----------|
| <b>in</b> | <i>n1</i> | Old label |
| <b>in</b> | <i>n2</i> | New label |

**void RenumberSide ( size\_t *n1*, size\_t *n2* )**

Renumber a side.

Parameters

|           |           |           |
|-----------|-----------|-----------|
| <b>in</b> | <i>n1</i> | Old label |
| <b>in</b> | <i>n2</i> | New label |



**void RenumberEdge ( size\_t *n1*, size\_t *n2* )**

Renumber an edge.

Parameters

|                 |                 |           |
|-----------------|-----------------|-----------|
| <code>in</code> | <code>n1</code> | Old label |
| <code>in</code> | <code>n2</code> | New label |

**void setNodeView ( size\_t n1, size\_t n2 )**

Set viewing window for nodes.

Parameters

|                 |                 |                    |
|-----------------|-----------------|--------------------|
| <code>in</code> | <code>n1</code> | First node to view |
| <code>in</code> | <code>n2</code> | last node to view  |

**void setElementView ( size\_t n1, size\_t n2 )**

Set viewing window for elements.

Parameters

|                 |                 |                       |
|-----------------|-----------------|-----------------------|
| <code>in</code> | <code>n1</code> | First element to view |
| <code>in</code> | <code>n2</code> | last element to view  |

**void setSideView ( size\_t n1, size\_t n2 )**

Set viewing window for sides.

Parameters

|                 |                 |                    |
|-----------------|-----------------|--------------------|
| <code>in</code> | <code>n1</code> | First side to view |
| <code>in</code> | <code>n2</code> | last side to view  |

**void setEdgeView ( size\_t n1, size\_t n2 )**

Set viewing window for edges.

Parameters

|                 |                 |                    |
|-----------------|-----------------|--------------------|
| <code>in</code> | <code>n1</code> | First edge to view |
| <code>in</code> | <code>n2</code> | last edge to view  |

**void setList ( const std::vector< Node \* > & nl )**

Initialize list of mesh nodes using the input vector.

Parameters

|                 |                 |                                                             |
|-----------------|-----------------|-------------------------------------------------------------|
| <code>in</code> | <code>nl</code> | vector instance that contains the list of pointers to nodes |
|-----------------|-----------------|-------------------------------------------------------------|

**void setList ( const std::vector< Element \* > & el )**

Initialize list of mesh elements using the input vector.

Parameters

|           |           |                                                                |
|-----------|-----------|----------------------------------------------------------------|
| <i>in</i> | <i>el</i> | vector instance that contains the list of pointers to elements |
|-----------|-----------|----------------------------------------------------------------|

**void setList ( const std::vector< Side \* > & *sl* )**

Initialize list of mesh sides using the input vector.

Parameters

|           |           |                                                             |
|-----------|-----------|-------------------------------------------------------------|
| <i>in</i> | <i>sl</i> | vector instance that contains the list of pointers to sides |
|-----------|-----------|-------------------------------------------------------------|

**void Rescale ( real.t *sx*, real.t *sy* = 0., real.t *sz* = 0. )**

Rescale mesh by multiplying node coordinates by constants.

This function can be used e.g. for changing coordinate units

Parameters

|           |           |                                                           |
|-----------|-----------|-----------------------------------------------------------|
| <i>in</i> | <i>sx</i> | Factor to multiply by x coordinates                       |
| <i>in</i> | <i>sy</i> | Factor to multiply by y coordinates [Default: <i>sx</i> ] |
| <i>in</i> | <i>sz</i> | Factor to multiply by z coordinates [Default: <i>sx</i> ] |

**size.t getNbBoundarySides ( ) const**

Return number of boundary sides.

This function is valid if member function **getAllSides** or **getBoundarySides** has been invoked before

**size.t getNbInternalSides ( ) const**

Return number of internal sides.

This function is valid if member functions **getAllSides** and **createInternalSideList** have been invoked before

**void AddMidNodes ( int *g* = 0 )**

Add mid-side nodes.

This is function is valid for triangles only

Parameters

|           |          |                                                                  |
|-----------|----------|------------------------------------------------------------------|
| <i>in</i> | <i>g</i> | Option to say if barycentre node is to be added (>0) or not (=0) |
|-----------|----------|------------------------------------------------------------------|

**void set ( Node \* *nd* )**

Replace node in the mesh.

If the node label exists already, the existing node pointer will be replaced by the current one. If not, an error message is displayed.

Parameters

|           |           |                 |
|-----------|-----------|-----------------|
| <i>in</i> | <i>nd</i> | Pointer to node |
|-----------|-----------|-----------------|

**void set ( Element \* *el* )**

Replace element in the mesh.

If the element label exists already, the existing element pointer will be replaced by the current one. If not, an error message is displayed.

Parameters

|           |           |                    |
|-----------|-----------|--------------------|
| <i>in</i> | <i>el</i> | Pointer to element |
|-----------|-----------|--------------------|

**void set ( Side \* *sd* )**

Choose side in the mesh.

If the side label exists already, the existing side pointer will be replaced by the current one. If not, an error message is displayed.

Parameters

|           |           |                 |
|-----------|-----------|-----------------|
| <i>in</i> | <i>sd</i> | Pointer to side |
|-----------|-----------|-----------------|

**bool NodesAreDOF ( ) const**

Return information about DOF type.

Returns

true if DOF are supported by nodes, false otherwise

**bool SidesAreDOF ( ) const**

Return information about DOF type.

Returns

true if DOF are supported by sides, false otherwise

**bool EdgesAreDOF ( ) const**

Return information about DOF type.

Returns

true if DOF are supported by edges, false otherwise

**bool ElementsAreDOF ( ) const**

Return information about DOF type.

Returns

true if DOF are supported by elements, false otherwise

**void put ( const string & *mesh\_file* ) const**

Write mesh data on file.

Parameters

|    |                  |                |
|----|------------------|----------------|
| in | <i>mesh_file</i> | Mesh file name |
|----|------------------|----------------|

**void save ( const string & *mesh\_file* ) const**

Write mesh data on file in various formats.

File format depends on the extension in file name

Parameters

|    |                  |                                                                                                                                                                                                                                                                                        |
|----|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh_file</i> | Mesh file name If the extension is '.m', the output file is an <a href="#">OFELI</a> file If the extension is '.gpl', the output file is a Gnuplot file If the extension is '.msh' or '.geo', the output file is a Gmsh file If the extension is '.vtk', the output file is a VTK file |
|----|------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void Bput ( const string & *mesh\_file* ) const**

Write mesh data on a binary file.

Parameters

|    |                  |                |
|----|------------------|----------------|
| in | <i>mesh_file</i> | Mesh file name |
|----|------------------|----------------|

**void getList ( vector< Node \* > & *nl* ) const**

Fill vector *nl* with list of pointers to nodes.

Parameters

|     |           |                                                          |
|-----|-----------|----------------------------------------------------------|
| out | <i>nl</i> | Instance of class vector that contain on output the list |
|-----|-----------|----------------------------------------------------------|

**void getList ( vector< Element \* > & *el* ) const**

Fill vector *el* with list of pointers to elements.

Parameters

|     |           |                                                          |
|-----|-----------|----------------------------------------------------------|
| out | <i>el</i> | Instance of class vector that contain on output the list |
|-----|-----------|----------------------------------------------------------|

**void getList ( vector< Side \* > & *sl* ) const**

Fill vector *sl* with list of pointers to sides.

Parameters

|     |           |                                                          |
|-----|-----------|----------------------------------------------------------|
| out | <i>sl</i> | Instance of class vector that contain on output the list |
|-----|-----------|----------------------------------------------------------|

**size\_t getNodeLabel ( size\_t *i* ) const**

Return label of *i*-th node.

Parameters

|    |          |                            |
|----|----------|----------------------------|
| in | <i>i</i> | <a href="#">Node</a> index |
|----|----------|----------------------------|

**size\_t getElementLabel ( size\_t *i* ) const**

Return label of *i*-th element.

Parameters

|                 |                |                               |
|-----------------|----------------|-------------------------------|
| <code>in</code> | <code>i</code> | <a href="#">Element</a> index |
|-----------------|----------------|-------------------------------|

**`size_t getSideLabel ( size_t i ) const`**

Return label of i-th side.

Parameters

|                 |                |                            |
|-----------------|----------------|----------------------------|
| <code>in</code> | <code>i</code> | <a href="#">Side</a> index |
|-----------------|----------------|----------------------------|

**`size_t getEdgeLabel ( size_t i ) const`**

Return label of i-th edge.

Parameters

|                 |                |                            |
|-----------------|----------------|----------------------------|
| <code>in</code> | <code>i</code> | <a href="#">Edge</a> index |
|-----------------|----------------|----------------------------|

**`Element* getActiveElement ( ) const`**

Return pointer to current element and move to next one (Non constant version)

This function returns pointer to the current element only if this one is active. Otherwise it goes to the next active element (To be used when adaptive meshing is involved)

#### 7.66.4 Friends And Related Function Documentation

**`void Refine ( Mesh & in_mesh, Mesh & out_mesh )`** [[friend](#)]

Refine mesh. Subdivide each triangle into 4 subtriangles. This member function is valid for 2-D triangular meshes only.

Parameters

|                  |                       |             |
|------------------|-----------------------|-------------|
| <code>in</code>  | <code>in_mesh</code>  | Input mesh  |
| <code>out</code> | <code>out_mesh</code> | Output mesh |

## 7.67 MeshAdapt Class Reference

To adapt mesh in function of given solution.

### Public Member Functions

- [MeshAdapt](#) ()  
*Default constructor.*
- [MeshAdapt](#) ([Mesh](#) &ms)  
*Constructor using initial mesh.*
- [MeshAdapt](#) ([Domain](#) &dom)  
*Constructor using a reference to class [Domain](#).*
- [~MeshAdapt](#) ()  
*Destructor.*
- [Domain](#) & [getDomain](#) () const  
*Get reference to [Domain](#) instance.*

- `Mesh & getMesh ()` const  
*Get reference to current mesh.*
- `void set (Domain &dom)`  
*Set reference to `Domain` instance.*
- `void set (Mesh &ms)`  
*Set reference to `Mesh` instance.*
- `void setSolution (const Vect< real_t > &u)`  
*Define label of node.*
- `void setJacobi (int n)`  
*Set number of Jacobi iterations for smoothing.*
- `void setSmooth (int n)`  
*Set number of smoothing iterations.*
- `void setVerbosity (int verb)`  
*Set verbosity parameter.*
- `void AbsoluteError ()`  
*Metric is constructed with absolute error.*
- `void RelativeError ()`  
*Metric is constructed with relative error.*
- `void setError (real_t err)`  
*Set error threshold for adaption.*
- `void setHMin (real_t h)`  
*Set minimal mesh size.*
- `void setHMax (real_t h)`  
*Set maximal mesh size.*
- `void setHMinAnisotropy (real_t h)`  
*Set minimal mesh size and set anisotropy.*
- `void setRelaxation (real_t omega)`  
*Set relaxation parameter for smoothing.*
- `void setAnisotropic ()`  
*Set that adapted mesh construction is anisotropic.*
- `void MaxAnisotropy (real_t a)`  
*Set maximum ratio of anisotropy.*
- `void setMaxSubdiv (real_t s)`  
*Change the metric such that the maximal subdivision of a background's edge is bounded by the given number (always limited by 10)*
- `void setMaxNbVertices (size_t n)`  
*Set maximum number of vertices.*
- `void setRatio (real_t r)`  
*Set ratio for a smoothing of the metric.*
- `void setNoScaling ()`  
*Do not scale solution before metric computation.*
- `void setNoKeep ()`  
*Do not keep old vertices.*
- `void setHessian ()`  
*set computation of the Hessian*
- `void setOutputMesh (string file)`  
*Create mesh output file.*

- void [setGeoFile](#) (string file)  
*Set Geometry file.*
- void [setGeoError](#) (real.t e)  
*Set error on geometry.*
- void [setBackgroundMesh](#) (string bgm)  
*Set background mesh.*
- void [SplitBoundaryEdges](#) ()  
*Split edges with two vertices on boundary.*
- void [CreateMetricFile](#) (string mf)  
*Create a metric file.*
- void [setMetricFile](#) (string mf)  
*Set Metric file.*
- void [getSolutionMbb](#) (string mbb)  
*Set solution defined on background mesh for metric construction.*
- void [getSolutionMBB](#) (string mBB)  
*Set solution defined on background mesh for metric construction.*
- void [getSolutionbb](#) (string rbb)  
*Read solution defined on the background mesh in bb file.*
- void [getSolutionBB](#) (string rBB)  
*Read solution defined on the background mesh in BB file.*
- void [getSolution](#) (Vect< real.t > &u, int is=1)  
*Get the interpolated solution on the new mesh.*
- void [getInterpolatedSolutionbb](#) ()  
*Write the file of interpolation of the solutions in bb file.*
- void [getInterpolatedSolutionBB](#) ()  
*Write the file of interpolation of the solutions in BB file.*
- void [setTheta](#) (real.t theta)  
*Set angular limit for a corner (in degrees)*
- void [Split](#) ()  
*Split triangles into 4 triangles.*
- void [saveMbb](#) (string file, const Vect< real.t > &u)  
*Save a solution in metric file.*
- int [run](#) ()  
*Run adaption process.*

### 7.67.1 Detailed Description

To adapt mesh in function of given solution.

Class [MeshAdapt](#) enables modifying mesh according to a solution vector defining at nodes. It concerns 2-D triangular meshes only.

Remarks

Class [MeshAdapt](#) is mainly based on the software ‘Bamg’ developed by F. Hecht, Universite Pierre et Marie Curie, Paris. We warmly thank him for accepting incorporation of Bamg in the [OFELI](#) package

### 7.67.2 Constructor & Destructor Documentation

[MeshAdapt](#) ( [Mesh](#) & ms )

Constructor using initial mesh.



Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <i>in</i> | <i>ms</i> | Reference to initial mesh |
|-----------|-----------|---------------------------|

### **MeshAdapt ( Domain & *dom* )**

Constructor using a reference to class [Domain](#).

Parameters

|           |            |                                           |
|-----------|------------|-------------------------------------------|
| <i>in</i> | <i>dom</i> | Reference to <a href="#">Domain</a> class |
|-----------|------------|-------------------------------------------|

## **7.67.3 Member Function Documentation**

### **void setRelaxation ( real.t *omega* )**

Set relaxation parameter for smoothing.

Default value for relaxation parameter is 1.8

### **void setMaxNbVertices ( size.t *n* )**

Set maximum number of vertices.

Default value is 500000

### **void setRatio ( real.t *r* )**

Set ratio for a smoothing of the metric.

Parameters

|           |          |              |
|-----------|----------|--------------|
| <i>in</i> | <i>r</i> | Ratio value. |
|-----------|----------|--------------|

Note

If *r* is 0 then no smoothing is performed, if *r* lies in [1.1, 10] then the smoothing changes the metric such that the largest geometrical progression (speed of mesh size variation in mesh is bounded by *r* (by default no smoothing)

### **void setNoScaling ( )**

Do not scale solution before metric computation.

By default, solution is scaled (between 0 and 1)

### **void setNoKeep ( )**

Do not keep old vertices.

By default, old vertices are kept

### **void getSolutionbb ( string *rbb* )**

Read solution defined on the background mesh in bb file.

Solution is interpolated on created mesh

### **void getSolutionBB ( string *rBB* )**

Read solution defined on the background mesh in BB file.

Solution is interpolated on created mesh

**void getSolution ( Vect< real.t > &u, int is = 1 )**

Get the interpolated solution on the new mesh.

The solution must have been saved on an output bb file

Parameters

|     |    |                                                                                                        |
|-----|----|--------------------------------------------------------------------------------------------------------|
| out | u  | Vector that contains on output the obtained solutions. This vector is resized before being initialized |
| in  | is | [Default: 1]                                                                                           |

**void setTheta ( real.t theta )**

Set angular limit for a corner (in degrees)

The angle is defined from 2 normals of 2 consecutive edges

**void saveMbb ( string file, const Vect< real.t > &u )**

Save a solution in metric file.

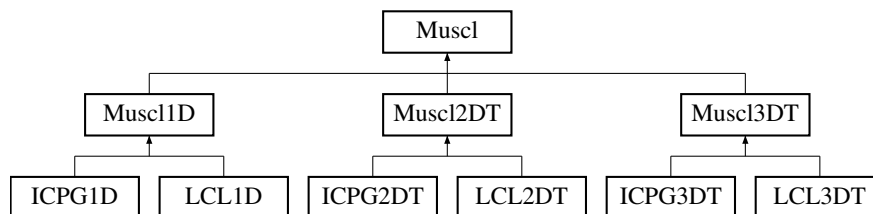
Parameters

|    |      |                                      |
|----|------|--------------------------------------|
| in | file | File name where the metric is stored |
| in | u    | Solution vector to store             |

## 7.68 Muscl Class Reference

Parent class for hyperbolic solvers with Muscl scheme.

Inheritance diagram for Muscl:



### Public Types

- enum **Method** {  
**FIRST\_ORDER\_METHOD** = 0,  
**MULTI.SLOPE.Q.METHOD** = 1,  
**MULTI.SLOPE.M.METHOD** = 2 }

*Enumeration for flux choice.*

- enum **Limiter** {  
**MINMOD\_LIMITER** = 0,  
**VANLEER\_LIMITER** = 1,  
**SUPERBEE\_LIMITER** = 2,  
**VANALBADA\_LIMITER** = 3,  
**MAX\_LIMITER** = 4 }

*Enumeration of flux limiting methods.*

- enum SolverType {  
ROE\_SOLVER = 0,  
VFROE\_SOLVER = 1,  
LF\_SOLVER = 2,  
RUSANOV\_SOLVER = 3,  
HLL\_SOLVER = 4,  
HLLC\_SOLVER = 5,  
MAX\_SOLVER = 6 }

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- Muscl (Mesh &m)  
*Constructor using mesh instance.*
- virtual ~Muscl ()  
*Destructor.*
- void setTimeStep (real.t dt)  
*Assign time step value.*
- real.t getTimeStep () const  
*Return time step value.*
- void setCFL (real.t CFL)  
*Assign CFL value.*
- real.t getCFL () const  
*Return CFL value.*
- void setReferenceLength (real.t dx)  
*Assign reference length value.*
- real.t getReferenceLength () const  
*Return reference length.*
- Mesh & getMesh () const  
*Return reference to Mesh instance.*
- void setVerbose (int v)  
*Set verbosity parameter.*
- bool setReconstruction (const Vect< real.t > &U, Vect< real.t > &LU, Vect< real.t > &RU, size.t dof)  
*Function to reconstruct by the Muscl method.*
- void setMethod (const Method &s)  
*Choose a flux solver.*
- void setSolidZoneCode (int c)  
*Choose a code for solid zone.*
- bool getSolidZone () const  
*Return flag for presence of solid zones.*
- int getSolidZoneCode () const  
*Return code of solid zone, 0 if this one is not present.*
- void setLimiter (Limiter l)  
*Choose a flux limiter.*

### 7.68.1 Detailed Description

Parent class for hyperbolic solvers with Muscl scheme.

Everything here is common for both 2D and 3D muscl methods ! Virtual functions are implemented in Muscl2D and Muscl3D classes

### 7.68.2 Member Enumeration Documentation

#### enum Method

Enumeration for flux choice.

Enumerator

*FIRST\_ORDER\_METHOD* First Order upwind method  
*MULTI\_SLOPE\_Q\_METHOD* Multislope Q method  
*MULTI\_SLOPE\_M\_METHOD* Multislope M method

#### enum Limiter

Enumeration of flux limiting methods.

Enumerator

*MINMOD\_LIMITER* MinMod limiter  
*VANLEER\_LIMITER* Van Leer limiter  
*SUPERBEE\_LIMITER* Superbee limiter  
*VANALBADA\_LIMITER* Van Albada limiter  
*MAX\_LIMITER* Max limiter

#### enum SolverType

Enumeration of various solvers for the Riemann problem.

Enumerator

*ROE\_SOLVER* Roe solver  
*VFROE\_SOLVER* Finite Volume Roe solver  
*LF\_SOLVER* LF solver  
*RUSANOV\_SOLVER* Rusanov solver  
*HLL\_SOLVER* HLL solver  
*HLLC\_SOLVER* HLLC solver  
*MAX\_SOLVER* Max solver

### 7.68.3 Member Function Documentation

**void setTimeStep ( real\_t dt )**

Assign time step value.

Parameters

|    |      |                 |
|----|------|-----------------|
| in | $dt$ | Time step value |
|----|------|-----------------|

**void setCFL ( real.t CFL )**

Assign CFL value.

Parameters

|    |       |              |
|----|-------|--------------|
| in | $CFL$ | Value of CFL |
|----|-------|--------------|

**void setReferenceLength ( real.t dx )**

Assign reference length value.

Parameters

|    |      |                           |
|----|------|---------------------------|
| in | $dx$ | Value of reference length |
|----|------|---------------------------|

**void setVerbose ( int v )**

Set verbosity parameter.

Parameters

|    |     |                              |
|----|-----|------------------------------|
| in | $v$ | Value of verbosity parameter |
|----|-----|------------------------------|

**bool setReconstruction ( const Vect< real.t > & U, Vect< real.t > & LU, Vect< real.t > & RU, size.t dof )**

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void setMethod ( const Method & s )**

Choose a flux solver.

Parameters

|    |     |                  |
|----|-----|------------------|
| in | $s$ | Solver to choose |
|----|-----|------------------|

**void setLimiter ( Limiter l )**

Choose a flux limiter.

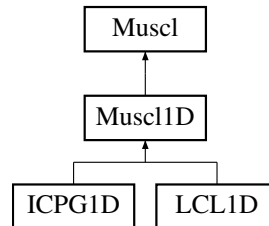
Parameters

|    |   |                   |
|----|---|-------------------|
| in | l | Limiter to choose |
|----|---|-------------------|

## 7.69 Muscl1D Class Reference

Class for 1-D hyperbolic solvers with [Muscl](#) scheme.

Inheritance diagram for Muscl1D:



### Public Types

- enum [Method](#) {  
[FIRST\\_ORDER\\_METHOD](#) = 0,  
[MULTI\\_SLOPE\\_Q\\_METHOD](#) = 1,  
[MULTI\\_SLOPE\\_M\\_METHOD](#) = 2 }

*Enumeration for flux choice.*

- enum [Limiter](#) {  
[MINMOD\\_LIMITER](#) = 0,  
[VANLEER\\_LIMITER](#) = 1,  
[SUPERBEE\\_LIMITER](#) = 2,  
[VANALBADA\\_LIMITER](#) = 3,  
[MAX\\_LIMITER](#) = 4 }

*Enumeration of flux limiting methods.*

- enum [SolverType](#) {  
[ROE\\_SOLVER](#) = 0,  
[VFROE\\_SOLVER](#) = 1,  
[LF\\_SOLVER](#) = 2,  
[RUSANOV\\_SOLVER](#) = 3,  
[HLL\\_SOLVER](#) = 4,  
[HLLC\\_SOLVER](#) = 5,  
[MAX\\_SOLVER](#) = 6 }

*Enumeration of various solvers for the Riemann problem.*

### Public Member Functions

- [Muscl1D](#) ([Mesh](#) &m)  
*Constructor using mesh instance.*
- [~Muscl1D](#) ()  
*Destructor.*
- [real.t](#) [getMeanLength](#) () const  
*Return mean length.*
- [real.t](#) [getMaximumLength](#) () const

- *Return maximal length.*  
• `real.t getMinimumLength () const`
- *Return mimal length.*  
• `real.t getTauLim () const`
- *Return mean length.*  
• `void print_mesh_stat ()`
- *Output mesh information.*  
• `void setTimeStep (real.t dt)`
- *Assign time step value.*  
• `real.t getTimeStep () const`
- *Return time step value.*  
• `void setCFL (real.t CFL)`
- *Assign CFL value.*  
• `real.t getCFL () const`
- *Return CFL value.*  
• `void setReferenceLength (real.t dx)`
- *Assign reference length value.*  
• `real.t getReferenceLength () const`
- *Return reference length.*  
• `Mesh & getMesh () const`
- *Return reference to `Mesh` instance.*  
• `void setVerbose (int v)`
- *Set verbosity parameter.*  
• `bool setReconstruction (const Vect< real.t > &U, Vect< real.t > &LU, Vect< real.t > &RU, size.t dof)`
- *Function to reconstruct by the `Muscl` method.*  
• `void setMethod (const Method &s)`
- *Choose a flux solver.*  
• `void setSolidZoneCode (int c)`
- *Choose a code for solid zone.*  
• `bool getSolidZone () const`
- *Return flag for presence of solid zones.*  
• `int getSolidZoneCode () const`
- *Return code of solid zone, 0 if this one is not present.*  
• `void setLimiter (Limiter l)`
- *Choose a flux limiter.*

### 7.69.1 Detailed Description

Class for 1-D hyperbolic solvers with `Muscl` scheme.

### 7.69.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

`FIRST_ORDER_METHOD` First Order upwind method

`MULTI_SLOPE_Q_METHOD` Multislope Q method

`MULTI_SLOPE_M_METHOD` Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

*MINMOD\_LIMITER* MinMod limiter  
*VANLEER\_LIMITER* Van Leer limiter  
*SUPERBEE\_LIMITER* Superbee limiter  
*VANALBADA\_LIMITER* Van Albada limiter  
*MAX\_LIMITER* Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

*ROE\_SOLVER* Roe solver  
*VFROE\_SOLVER* Finite Volume Roe solver  
*LF\_SOLVER* LF solver  
*RUSANOV\_SOLVER* Rusanov solver  
*HLL\_SOLVER* HLL solver  
*HLLC\_SOLVER* HLLC solver  
*MAX\_SOLVER* Max solver

**7.69.3 Member Function Documentation****void setTimeStep ( real\_t dt )** [inherited]

Assign time step value.

Parameters

|    |    |                 |
|----|----|-----------------|
| in | dt | Time step value |
|----|----|-----------------|

**void setCFL ( real\_t CFL )** [inherited]

Assign CFL value.

Parameters

|    |     |              |
|----|-----|--------------|
| in | CFL | Value of CFL |
|----|-----|--------------|

**void setReferenceLength ( real\_t dx )** [inherited]

Assign reference length value.

Parameters



|    |      |                           |
|----|------|---------------------------|
| in | $dx$ | Value of reference length |
|----|------|---------------------------|

**void setVerbose ( int  $v$  )** [inherited]

Set verbosity parameter.

Parameters

|    |     |                              |
|----|-----|------------------------------|
| in | $v$ | Value of verbosity parameter |
|----|-----|------------------------------|

**bool setReconstruction ( const Vect< real.t > &  $U$ , Vect< real.t > &  $LU$ , Vect< real.t > &  $RU$ , size.t  $dof$  )** [inherited]

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |       |                             |
|-----|-------|-----------------------------|
| in  | $U$   | Field to reconstruct        |
| out | $LU$  | Left gradient vector        |
| out | $RU$  | Right gradient vector       |
| in  | $dof$ | Label of dof to reconstruct |

**void setMethod ( const Method &  $s$  )** [inherited]

Choose a flux solver.

Parameters

|    |     |                  |
|----|-----|------------------|
| in | $s$ | Solver to choose |
|----|-----|------------------|

**void setLimiter ( Limiter  $l$  )** [inherited]

Choose a flux limiter.

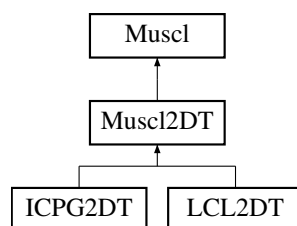
Parameters

|    |     |                   |
|----|-----|-------------------|
| in | $l$ | Limiter to choose |
|----|-----|-------------------|

## 7.70 Muscl2DT Class Reference

Class for 2-D hyperbolic solvers with [Muscl](#) scheme.

Inheritance diagram for Muscl2DT:



## Public Types

- enum `Method` {  
`FIRST_ORDER_METHOD` = 0,  
`MULTI_SLOPE_Q_METHOD` = 1,  
`MULTI_SLOPE_M_METHOD` = 2 }

*Enumeration for flux choice.*

- enum `Limiter` {  
`MINMOD_LIMITER` = 0,  
`VANLEER_LIMITER` = 1,  
`SUPERBEE_LIMITER` = 2,  
`VANALBADA_LIMITER` = 3,  
`MAX_LIMITER` = 4 }

*Enumeration of flux limiting methods.*

- enum `SolverType` {  
`ROE_SOLVER` = 0,  
`VFROE_SOLVER` = 1,  
`LF_SOLVER` = 2,  
`RUSANOV_SOLVER` = 3,  
`HLL_SOLVER` = 4,  
`HLLC_SOLVER` = 5,  
`MAX_SOLVER` = 6 }

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- `Muscl2DT` (`Mesh &m`)  
*Constructor using mesh.*
- `~Muscl2DT` ()  
*Destructor.*
- bool `setReconstruction` (const `Vect< real_t > &U`, `Vect< real_t > &LU`, `Vect< real_t > &RU`, `size_t dof`)  
*Function to reconstruct by the `Muscl` method.*
- void `setTimeStep` (`real_t dt`)  
*Assign time step value.*
- `real_t getTimeStep` () const  
*Return time step value.*
- void `setCFL` (`real_t CFL`)  
*Assign CFL value.*
- `real_t getCFL` () const  
*Return CFL value.*
- void `setReferenceLength` (`real_t dx`)  
*Assign reference length value.*
- `real_t getReferenceLength` () const  
*Return reference length.*
- `Mesh &getMesh` () const  
*Return reference to `Mesh` instance.*
- void `setVerbose` (int v)  
*Set verbosity parameter.*
- void `setMethod` (const `Method &s`)

- *Choose a flux solver.*
- void `setSolidZoneCode` (int c)  
*Choose a code for solid zone.*
- bool `getSolidZone` () const  
*Return flag for presence of solid zones.*
- int `getSolidZoneCode` () const  
*Return code of solid zone, 0 if this one is not present.*
- void `setLimiter` (`Limiter` l)  
*Choose a flux limiter.*

## Protected Member Functions

- void `Initialize` ()  
*Construction of normals to sides.*

### 7.70.1 Detailed Description

Class for 2-D hyperbolic solvers with `Muscl` scheme.

### 7.70.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

`FIRST_ORDER_METHOD` First Order upwind method  
`MULTI_SLOPE_Q_METHOD` Multislope Q method  
`MULTI_SLOPE_M_METHOD` Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

`MINMOD_LIMITER` MinMod limiter  
`VANLEER_LIMITER` Van Leer limiter  
`SUPERBEE_LIMITER` Superbee limiter  
`VANALBADA_LIMITER` Van Albada limiter  
`MAX_LIMITER` Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

`ROE_SOLVER` Roe solver  
`VFROE_SOLVER` Finite Volume Roe solver

**LF\_SOLVER** LF solver

**RUSANOV\_SOLVER** Rusanov solver

**HLL\_SOLVER** HLL solver

**HLLC\_SOLVER** HLLC solver

**MAX\_SOLVER** Max solver

### 7.70.3 Member Function Documentation

**bool setReconstruction ( const Vect< real.t > & *U*, Vect< real.t > & *LU*, Vect< real.t > & *RU*, size.t *dof* )**

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |            |                             |
|-----|------------|-----------------------------|
| in  | <i>U</i>   | Field to reconstruct        |
| out | <i>LU</i>  | Left gradient vector        |
| out | <i>RU</i>  | Right gradient vector       |
| in  | <i>dof</i> | Label of dof to reconstruct |

**void Initialize ( )** [protected]

Construction of normals to sides.

Convention: for a given side, getPtrElement(1) is the left element and getPtrElement(2) is the right element. The normal goes from left to right. For boundary sides, the normal points outward.

**void setTimeStep ( real.t *dt* )** [inherited]

Assign time step value.

Parameters

|    |           |                 |
|----|-----------|-----------------|
| in | <i>dt</i> | Time step value |
|----|-----------|-----------------|

**void setCFL ( real.t *CFL* )** [inherited]

Assign CFL value.

Parameters

|    |            |              |
|----|------------|--------------|
| in | <i>CFL</i> | Value of CFL |
|----|------------|--------------|

**void setReferenceLength ( real.t *dx* )** [inherited]

Assign reference length value.

Parameters

|    |           |                           |
|----|-----------|---------------------------|
| in | <i>dx</i> | Value of reference length |
|----|-----------|---------------------------|

**void setVerbose ( int *v* )** [inherited]

Set verbosity parameter.

Parameters

|    |          |                              |
|----|----------|------------------------------|
| in | <i>v</i> | Value of verbosity parameter |
|----|----------|------------------------------|

**void setMethod ( const Method & s )** [inherited]

Choose a flux solver.

Parameters

|    |          |                  |
|----|----------|------------------|
| in | <i>s</i> | Solver to choose |
|----|----------|------------------|

**void setLimiter ( Limiter l )** [inherited]

Choose a flux limiter.

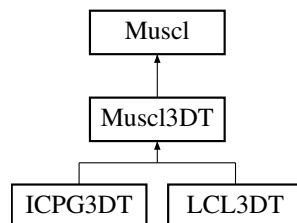
Parameters

|    |          |                   |
|----|----------|-------------------|
| in | <i>l</i> | Limiter to choose |
|----|----------|-------------------|

## 7.71 Muscl3DT Class Reference

Class for 3-D hyperbolic solvers with [Muscl](#) scheme using tetrahedra.

Inheritance diagram for Muscl3DT:



### Public Types

- enum [Method](#) {  
[FIRST\\_ORDER\\_METHOD](#) = 0,  
[MULTI\\_SLOPE\\_Q\\_METHOD](#) = 1,  
[MULTI\\_SLOPE\\_M\\_METHOD](#) = 2 }

*Enumeration for flux choice.*

- enum [Limiter](#) {  
[MINMOD\\_LIMITER](#) = 0,  
[VANLEER\\_LIMITER](#) = 1,  
[SUPERBEE\\_LIMITER](#) = 2,  
[VANALBADA\\_LIMITER](#) = 3,  
[MAX\\_LIMITER](#) = 4 }

*Enumeration of flux limiting methods.*

- enum [SolverType](#) {

```

ROE_SOLVER = 0,
VFROE_SOLVER = 1,
LF_SOLVER = 2,
RUSANOV_SOLVER = 3,
HLL_SOLVER = 4,
HLLC_SOLVER = 5,
MAX_SOLVER = 6 }

```

*Enumeration of various solvers for the Riemann problem.*

## Public Member Functions

- **Muscl3DT** (**Mesh** &m)  
*Constructor using mesh.*
- **~Muscl3DT** ()  
*Destructor.*
- **bool setReconstruction** (const **Vect**< **real.t** > &U, **Vect**< **real.t** > &LU, **Vect**< **real.t** > &RU, **size.t** dof)  
*Function to reconstruct by the **Muscl** method.*
- **real.t getMinimumFaceArea** () const  
*Return minimum area of faces in the mesh.*
- **real.t getMinimumElementVolume** () const  
*Return minimum volume of elements in the mesh.*
- **real.t getMaximumFaceArea** () const  
*Return maximum area of faces in the mesh.*
- **real.t getMaximumElementVolume** () const  
*Return maximum volume of elements in the mesh.*
- **real.t getMeanFaceArea** () const  
*Return mean area of faces in the mesh.*
- **real.t getMeanElementVolume** () const  
*Return mean volume of elements in the mesh.*
- **real.t getMinimumEdgeLength** () const  
*Return minimum length of edges in the mesh.*
- **real.t getMinimumVolumebyArea** () const  
*Return minimum volume by area in the mesh.*
- **real.t getMaximumEdgeLength** () const  
*Return maximum length of edges in the mesh.*
- **real.t getTauLim** () const  
*Return value of tau lim.*
- **real.t getComega** () const  
*Return value of Comega.*
- **void setbetalim** (**real.t** bl)  
*Assign value of beta lim.*
- **void setTimeStep** (**real.t** dt)  
*Assign time step value.*
- **real.t getTimeStep** () const  
*Return time step value.*
- **void setCFL** (**real.t** CFL)  
*Assign CFL value.*

- `real_t getCFL () const`  
*Return CFL value.*
- `void setReferenceLength (real_t dx)`  
*Assign reference length value.*
- `real_t getReferenceLength () const`  
*Return reference length.*
- `Mesh & getMesh () const`  
*Return reference to `Mesh` instance.*
- `void setVerbose (int v)`  
*Set verbosity parameter.*
- `void setMethod (const Method &s)`  
*Choose a flux solver.*
- `void setSolidZoneCode (int c)`  
*Choose a code for solid zone.*
- `bool getSolidZone () const`  
*Return flag for presence of solid zones.*
- `int getSolidZoneCode () const`  
*Return code of solid zone, 0 if this one is not present.*
- `void setLimiter (Limiter l)`  
*Choose a flux limiter.*

### 7.71.1 Detailed Description

Class for 3-D hyperbolic solvers with `Muscl` scheme using tetrahedra.

### 7.71.2 Member Enumeration Documentation

**enum Method** [inherited]

Enumeration for flux choice.

Enumerator

`FIRST_ORDER_METHOD` First Order upwind method

`MULTI_SLOPE_Q_METHOD` Multislope Q method

`MULTI_SLOPE_M_METHOD` Multislope M method

**enum Limiter** [inherited]

Enumeration of flux limiting methods.

Enumerator

`MINMOD_LIMITER` MinMod limiter

`VANLEER_LIMITER` Van Leer limiter

`SUPERBEE_LIMITER` Superbee limiter

`VANALBADA_LIMITER` Van Albada limiter

`MAX_LIMITER` Max limiter

**enum SolverType** [inherited]

Enumeration of various solvers for the Riemann problem.

Enumerator

**ROE\_SOLVER** Roe solver  
**VFROE\_SOLVER** Finite Volume Roe solver  
**LF\_SOLVER** LF solver  
**RUSANOV\_SOLVER** Rusanov solver  
**HLL\_SOLVER** HLL solver  
**HLLC\_SOLVER** HLLC solver  
**MAX\_SOLVER** Max solver

### 7.71.3 Member Function Documentation

**bool setReconstruction ( const Vect< real.t > & *U*, Vect< real.t > & *LU*, Vect< real.t > & *RU*, size.t *dof* )**

Function to reconstruct by the [Muscl](#) method.

Parameters

|     |            |                             |
|-----|------------|-----------------------------|
| in  | <i>U</i>   | Field to reconstruct        |
| out | <i>LU</i>  | Left gradient vector        |
| out | <i>RU</i>  | Right gradient vector       |
| in  | <i>dof</i> | Label of dof to reconstruct |

**void setTimeStep ( real.t *dt* )** [inherited]

Assign time step value.

Parameters

|    |           |                 |
|----|-----------|-----------------|
| in | <i>dt</i> | Time step value |
|----|-----------|-----------------|

**void setCFL ( real.t *CFL* )** [inherited]

Assign CFL value.

Parameters

|    |            |              |
|----|------------|--------------|
| in | <i>CFL</i> | Value of CFL |
|----|------------|--------------|

**void setReferenceLength ( real.t *dx* )** [inherited]

Assign reference length value.

Parameters

|    |           |                           |
|----|-----------|---------------------------|
| in | <i>dx</i> | Value of reference length |
|----|-----------|---------------------------|

**void setVerbose ( int *v* )** [inherited]

Set verbosity parameter.



Parameters

|    |   |                              |
|----|---|------------------------------|
| in | v | Value of verbosity parameter |
|----|---|------------------------------|

**void setMethod ( const Method & s )** [inherited]

Choose a flux solver.

Parameters

|    |   |                  |
|----|---|------------------|
| in | s | Solver to choose |
|----|---|------------------|

**void setLimiter ( Limiter l )** [inherited]

Choose a flux limiter.

Parameters

|    |   |                   |
|----|---|-------------------|
| in | l | Limiter to choose |
|----|---|-------------------|

## 7.72 Node Class Reference

To describe a node.

### Public Member Functions

- [Node](#) ()  
*Default constructor.*
- [Node](#) (size\_t label, const [Point](#)< real\_t > &x)  
*Constructor with label and coordinates.*
- [Node](#) (const [Node](#) &node)  
*Copy Constructor.*
- [~Node](#) ()  
*Destructor.*
- void [setLabel](#) (size\_t label)  
*Define label of node.*
- void [setNbDOF](#) (size\_t n)  
*Define number of DOF.*
- void [setFirstDOF](#) (size\_t n)  
*Define First DOF.*
- void [setCode](#) (size\_t dof, int code)  
*Define code for a given DOF of node.*
- void [setCode](#) (const vector< int > &code)  
*Define codes for all node DOFs.*
- void [setCode](#) (int \*code)  
*Define codes for all node DOFs.*
- void [setCode](#) (const string &exp, int code, size\_t dof=1)  
*Define code by a boolean algebraic expression invoking node coordinates.*
- void [setCoord](#) (size\_t i, real\_t x)  
*Set i-th coordinate.*
- void [DOF](#) (size\_t i, size\_t dof)

- Define label of DOF.*

  - void **setDOF** (size\_t &first\_dof, size\_t nb\_dof)

*Define number of DOF.*

  - void **setOnBoundary** ()

*Set node as boundary node.*

  - size\_t **n** () const

*Return label of node.*

  - size\_t **getNbDOF** () const

*Return number of degrees of freedom (DOF)*

  - int **getCode** (size\_t dof=1) const

*Return code for a given DOF of node.*

  - real\_t **getCoord** (size\_t i) const

*Return i-th coordinate of node. i = 1..3.*

  - **Point**< real\_t > **getCoord** () const

*Return coordinates of node.*

  - real\_t **getX** () const

*Return x-coordinate of node.*

  - real\_t **getY** () const

*Return y-coordinate of node.*

  - real\_t **getZ** () const

*Return z-coordinate of node.*

  - **Point**< real\_t > **getXYZ** () const

*Return coordinates of node.*

  - size\_t **getDOF** (size\_t i) const

*Return label of i-th dof.*

  - size\_t **getNbNeigEl** () const

*Return number of neighbor elements.*

  - **Element** \* **getNeigEl** (size\_t i) const

*Return i-th neighbor element.*

  - size\_t **getFirstDOF** () const

*Return label of first DOF of node.*

  - bool **isOnBoundary** () const

*Say if node is a boundary node.*

  - void **Add** (**Element** \*el)

*Add element pointed by el as neighbor element to node.*

  - void **setLevel** (int level)

*Assign a level to current node.*

  - int **getLevel** () const

*Return node level **Node** level decreases when element is refined (starting from 0). If the level is 0, then the element has no parents.*

### 7.72.1 Detailed Description

To describe a node.

A node is characterized by its label, its coordinates, its number of degrees of freedom (DOF) and codes that are associated to each DOF.

Remarks

Once the mesh is constructed, information on neighboring elements of node can be retrieved (see appropriate member functions). However, the member function `getNodeNeighborElements` of `Mesh` must have been called before. If this is not the case, the program crashes down since no preliminary checking is done for efficiency reasons.

### 7.72.2 Constructor & Destructor Documentation

**Node ( )**

Default constructor.

Initialize data to zero

**Node ( *size\_t label*, *const Point< real\_t > & x* )**

Constructor with label and coordinates.

Parameters

|           |              |                  |
|-----------|--------------|------------------|
| <i>in</i> | <i>label</i> | Label of node    |
| <i>in</i> | <i>x</i>     | Node coordinates |

### 7.72.3 Member Function Documentation

**void setCode ( *size\_t dof*, *int code* )**

Define code for a given DOF of node.

Parameters

|           |             |                       |
|-----------|-------------|-----------------------|
| <i>in</i> | <i>dof</i>  | DOF index             |
| <i>in</i> | <i>code</i> | Code to assign to DOF |

**void setCode ( *const vector< int > & code* )**

Define codes for all node DOFs.

Parameters

|           |             |                                                                 |
|-----------|-------------|-----------------------------------------------------------------|
| <i>in</i> | <i>code</i> | vector instance that contains code for each DOF of current node |
|-----------|-------------|-----------------------------------------------------------------|

**void setCode ( *int \* code* )**

Define codes for all node DOFs.

Parameters

|           |             |                                                         |
|-----------|-------------|---------------------------------------------------------|
| <i>in</i> | <i>code</i> | C-array that contains code for each DOF of current node |
|-----------|-------------|---------------------------------------------------------|

**void setCode ( *const string & exp*, *int code*, *size\_t dof = 1* )**

Define code by a boolean algebraic expression invoking node coordinates.

Parameters

|           |             |                                                                  |
|-----------|-------------|------------------------------------------------------------------|
| <b>in</b> | <i>exp</i>  | Boolean algebraic expression as required by <code>fparser</code> |
| <b>in</b> | <i>code</i> | Code to assign to node if the algebraic expression is true       |
| <b>in</b> | <i>dof</i>  | Degree of Freedom for which code is assigned [Default: 1]        |

**void setCoord ( size\_t i, real\_t x )**

Set i-th coordinate.

Parameters

|           |          |                         |
|-----------|----------|-------------------------|
| <b>in</b> | <i>i</i> | Coordinate index (1..3) |
| <b>in</b> | <i>x</i> | Coordinate value        |

**void DOF ( size\_t i, size\_t dof )**

Define label of DOF.

Parameters

|           |            |              |
|-----------|------------|--------------|
| <b>in</b> | <i>i</i>   | DOF index    |
| <b>in</b> | <i>dof</i> | Label of DOF |

**void setDOF ( size\_t &first\_dof, size\_t nb\_dof )**

Define number of DOF.

Parameters

|               |                  |                                                    |
|---------------|------------------|----------------------------------------------------|
| <b>in,out</b> | <i>first_dof</i> | Label of the first DOF in input that is actualized |
| <b>in</b>     | <i>nb_dof</i>    | Number of DOF                                      |

**void setOnBoundary ( )**

Set node as boundary node.

This function is mostly internally used (Especially in class [Mesh](#))

**int getCode ( size\_t dof = 1 ) const**

Return code for a given DOF of node.

Parameters

|           |            |                                                                                  |
|-----------|------------|----------------------------------------------------------------------------------|
| <b>in</b> | <i>dof</i> | label of degree of freedom for which code is to be returned. Default value is 1. |
|-----------|------------|----------------------------------------------------------------------------------|

**Point<real\_t> getCoord ( ) const**

Return coordinates of node.

Return value is an instance of class [Point](#)

**Point<real\_t> getXYZ ( ) const**

Return coordinates of node.

Return value is an instance of class [Point](#)

**size\_t getNbNeigEl ( ) const**

Return number of neighbor elements.

Neighbor elements are those that share node. Note that the returned information is valid only if the [Mesh](#) member function **getNodeNeighborElements()** has been invoked before

**Element\* getNeigEl ( size\_t i ) const**

Return i-th neighbor element.

Note that the returned information is valid only if the [Mesh](#) member function **getNodeNeighborElements()** has been invoked before

**bool isOnBoundary ( ) const**

Say if node is a boundary node.

Note this information is available only if boundary sides (and nodes) were determined (See class [Mesh](#)).

**void setLevel ( int level )**

Assign a level to current node.

This member function is useful for mesh adaption.

Default node's level is zero

## 7.73 NodeList Class Reference

Class to construct a list of nodes having some common properties.

### Public Member Functions

- [NodeList](#) ([Mesh](#) &ms)
- Constructor using a [Mesh](#) instance.*
- [~NodeList](#) ()
- Destructor.*
- void [selectCode](#) (int code, int dof=1)
- Select nodes having a given code for a given degree of freedom.*
- void [unselectCode](#) (int code, int dof=1)
- Unselect nodes having a given code for a given degree of freedom.*
- void [selectCoordinate](#) ([real\\_t](#) x, [real\\_t](#) y=ANY, [real\\_t](#) z=ANY)
- Select nodes having given coordinates.*
- size\_t [getNbNodes](#) () const
- Return number of selected nodes.*
- void [top](#) ()
- Reset list of nodes at its top position (Non constant version)*
- void [top](#) () const
- Reset list of nodes at its top position (Constant version)*
- [Node](#) \* [get](#) ()
- Return pointer to current node and move to next one (Non constant version)*
- [Node](#) \* [get](#) () const
- Return pointer to current node and move to next one (Constant version)*

### 7.73.1 Detailed Description

Class to construct a list of nodes having some common properties.

This class enables choosing multiple selection criteria by using function `select...`. However, the intersection of these properties must be empty.

### 7.73.2 Member Function Documentation

**void selectCode ( int *code*, int *dof* = 1 )**

Select nodes having a given code for a given degree of freedom.

Parameters

|    |             |                                      |
|----|-------------|--------------------------------------|
| in | <i>code</i> | Code that nodes share                |
| in | <i>dof</i>  | Degree of Freedom label [Default: 1] |

**void unselectCode ( int *code*, int *dof* = 1 )**

Unselect nodes having a given code for a given degree of freedom.

Parameters

|    |             |                                      |
|----|-------------|--------------------------------------|
| in | <i>code</i> | Code of nodes to exclude             |
| in | <i>dof</i>  | Degree of Freedom label [Default: 1] |

**void selectCoordinate ( real.t *x*, real.t *y* = ANY, real.t *z* = ANY )**

Select nodes having given coordinates.

Parameters

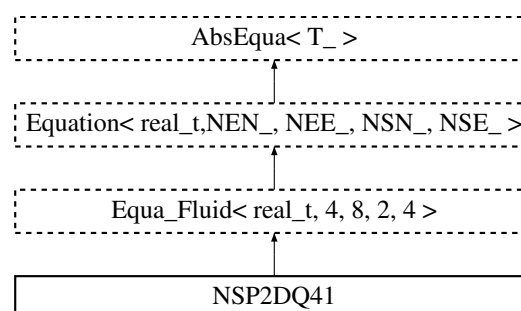
|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>x</i> | x-coordinate that share the selected nodes                |
| in | <i>y</i> | y-coordinate that share the selected nodes [Default: ANY] |
| in | <i>z</i> | z-coordinate that share the selected nodes [Default: ANY] |

Coordinates can be assigned the value ANY. This means that any coordinate value is accepted. For instance, to select all nodes with  $x=0$ , use `selectCoordinate(0.,ANY,ANY)`;

## 7.74 NSP2DQ41 Class Reference

Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using  $Q_1/P_0$  element and a penalty formulation for the incompressibility condition.

Inheritance diagram for NSP2DQ41:



## Public Member Functions

- [NSP2DQ41](#) ()  
*Default Constructor.*
- [NSP2DQ41](#) (const [Element](#) \*el)  
*Constructor using [Element](#) data.*
- [NSP2DQ41](#) (const [Side](#) \*sd)  
*Constructor using [Side](#) data.*
- [NSP2DQ41](#) (const [Element](#) \*el, const [Vect](#)< [real\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using element and previous time data.*
- [NSP2DQ41](#) (const [Side](#) \*sd, const [Vect](#)< [real\\_t](#) > &u, const [real\\_t](#) &time=0.)  
*Constructor using side and previous time data.*
- [~NSP2DQ41](#) ()  
*Destructor.*
- void [Viscosity](#) ([real\\_t](#) visc)  
*Define constant viscosity.*
- void [Density](#) ([real\\_t](#) dens)  
*Define constant density.*
- void [LMass](#) ([real\\_t](#) coef=1.)  
*Add element lumped mass contribution to matrix after multiplication by [coef](#) [Default: 1].*
- void [Mass](#) ([real\\_t](#) coef=1.)  
*Add element consistent mass contribution to matrix after multiplication by [coef](#) [Default: 1].*
- void [Viscous](#) ([real\\_t](#) coef=1.)  
*Add element viscous contribution to matrix after multiplication by [coef](#) [Default: 1].*
- void [RHS\\_Viscous](#) ([real\\_t](#) coef=1.)  
*Add element viscous contribution to right-hand side after multiplication by [coef](#) [Default: 1].*
- void [Penal](#) ([real\\_t](#) coef=1.)  
*Add element penalty contribution to matrix after multiplication by [coef](#) [Default: 1].*
- void [LHS1\\_Convection](#) ([real\\_t](#) coef=1.)  
*Add convection contribution to left-hand side after multiplication by [coef](#) [Default: 1].*
- void [LHS2\\_Convection](#) ([real\\_t](#) coef=1.)  
*Add convection contribution to left-hand side after multiplication by [coef](#) [Default: 1].*
- void [RHS\\_Convection](#) ([real\\_t](#) coef=1.)  
*Add convection contribution to right-hand side after multiplication by [coef](#) [Default: 1].*
- void [BodyRHS](#) ([UserData](#)< [real\\_t](#) > &ud)  
*Add body right-hand side term to right-hand side.*
- void [BoundaryRHS](#) ([UserData](#)< [real\\_t](#) > &ud)  
*Add boundary right-hand side term to right-hand side.*
- void [Periodic](#) ([real\\_t](#) coef=1.e20)  
*Add contribution of periodic boundary condition (by a penalty technique).*
- [real\\_t](#) [Pressure](#) ([real\\_t](#) coef=1.)  
*Calculate element pressure by penalization after multiplication by [coef](#) [Default: 1].*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< [T\\_](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [T\\_](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [DiagBC](#) (int dof\_type=NODE.DOF, int dof=0)

- Update element matrix to impose bc by diagonalization technique.*

  - void **LocalNodeVector** (**Vect**< T\_ > &b)

*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)

*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)

*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)

*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)

*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof.type=NODE.FIELD, int flag=0)

*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)

*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()

*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()

*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)

*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)

*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)

*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)

*Assemble side matrix into global one.*
- void **SideAssembly** (**PETScVect**< T\_ > &b)

*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (**Matrix**< T\_ > \*A)

*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkSMatrix**< T\_ > &A)

*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (**SkMatrix**< T\_ > &A)



- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*
  - size\_t [getNbNodes](#) () const
- Return number of element nodes.*
  - size\_t [getNbEq](#) () const
- Return number of element equations.*
  - void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*
  - [real\\_t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*
  - void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*
  - [Mesh](#) & [getMesh](#) () const
- Return reference to [Mesh](#) instance.*
  - [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
  - void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))
- Choose solver for the linear system.*
  - int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system.*

## Public Attributes

- [LocalMatrix](#)< T\_, NEE\_, NEE\_ > [eMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current element.*
- [LocalMatrix](#)< T\_, NSE\_, NSE\_ > [sMat](#)  
*[LocalMatrix](#) instance containing local matrix associated to current side.*
- [LocalVect](#)< T\_, NEE\_ > [ePrev](#)  
*[LocalVect](#) instance containing local vector associated to current element.*
- [LocalVect](#)< T\_, NEE\_ > [eRHS](#)

*LocalVect* instance containing local right-hand side vector associated to current element.

- `LocalVect< T-, NEE- > eRes`

*LocalVect* instance containing local residual vector associated to current element.

- `LocalVect< T-, NSE- > sRHS`

*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void `Viscosity` (const `real.t` &visc)  
*Set (constant) Viscosity.*
- void `Viscosity` (const string &exp)  
*Set viscosity given by an algebraic expression.*
- void `Density` (const `real.t` &dens)  
*Set (constant) Viscosity.*
- void `Density` (const string &exp)  
*Set Density given by an algebraic expression.*
- void `ThermalExpansion` (const `real.t` \*e)  
*Set (constant) thermal expansion coefficient.*
- void `ThermalExpansion` (const string &exp)  
*Set thermal expansion coefficient given by an algebraic expression.*
- void `setMaterial` ()  
*Set material properties.*
- void `Init` (const `Element` \*el)  
*Set element arrays to zero.*
- void `Init` (const `Side` \*sd)  
*Set side arrays to zero.*

### 7.74.1 Detailed Description

Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using  $Q_1/P_0$  element and a penalty formulation for the incompressibility condition.

### 7.74.2 Constructor & Destructor Documentation

`NSP2DQ41 ( )`

Default Constructor.

Builds an empty equation

`NSP2DQ41 ( const Element * el )`

Constructor using `Element` data.

Parameters

|                 |                 |                                          |
|-----------------|-----------------|------------------------------------------|
| <code>in</code> | <code>el</code> | Pointer to <code>Element</code> instance |
|-----------------|-----------------|------------------------------------------|

`NSP2DQ41 ( const Side * sd )`

Constructor using `Side` data.

Parameters

|                 |                 |                                          |
|-----------------|-----------------|------------------------------------------|
| <code>in</code> | <code>sd</code> | Pointer to <a href="#">Side</a> instance |
|-----------------|-----------------|------------------------------------------|

**NSP2DQ41 ( const Element \* *el*, const Vect< real.t > & *u*, const real.t & *time* = 0. )**

Constructor using element and previous time data.

Parameters

|                 |                   |                                                     |
|-----------------|-------------------|-----------------------------------------------------|
| <code>in</code> | <code>el</code>   | Pointer to <a href="#">Element</a> instance         |
| <code>in</code> | <code>u</code>    | Vector that contains velocity at previous time step |
| <code>in</code> | <code>time</code> | Time value [Default: 0.]                            |

**NSP2DQ41 ( const Side \* *sd*, const Vect< real.t > & *u*, const real.t & *time* = 0. )**

Constructor using side and previous time data.

Parameters

|                 |                   |                                                     |
|-----------------|-------------------|-----------------------------------------------------|
| <code>in</code> | <code>sd</code>   | Pointer to <a href="#">Side</a> instance            |
| <code>in</code> | <code>u</code>    | Vector that contains velocity at previous time step |
| <code>in</code> | <code>time</code> | Time value [Default: 0.]                            |

### 7.74.3 Member Function Documentation

**void LHS1\_Convection ( real.t *coef* = 1. )**

Add convection contribution to left-hand side after multiplication by *coef* [Default: 1].

First term, explicit velocity, implicit velocity derivatives

**void LHS2\_Convection ( real.t *coef* = 1. )**

Add convection contribution to left-hand side after multiplication by *coef* [Default: 1].

Second term, implicit velocity, explicit velocity derivatives

**void BodyRHS ( UserData< real.t > & *ud* )**

Add body right-hand side term to right-hand side.

Parameters

|                 |                 |                                                     |
|-----------------|-----------------|-----------------------------------------------------|
| <code>in</code> | <code>ud</code> | <a href="#">UserData</a> instance that defines data |
|-----------------|-----------------|-----------------------------------------------------|

**void BoundaryRHS ( UserData< real.t > & *ud* )**

Add boundary right-hand side term to right-hand side.

Parameters

|                 |                 |                                                     |
|-----------------|-----------------|-----------------------------------------------------|
| <code>in</code> | <code>ud</code> | <a href="#">UserData</a> instance that defines data |
|-----------------|-----------------|-----------------------------------------------------|

**void Periodic ( real.t *coef* = 1.e20 )**

Add contribution of periodic boundary condition (by a penalty technique).

Boundary nodes where periodic boundary conditions are to be imposed must have codes equal to PERIODIC.A on one side and PERIODIC.B on the opposite side.

Parameters

|                 |                   |                                              |
|-----------------|-------------------|----------------------------------------------|
| <code>in</code> | <code>coef</code> | Value of penalty parameter [Default: 1.e20]. |
|-----------------|-------------------|----------------------------------------------|

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>el</code> | Reference to current element instance           |
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|                 |                 |                                                 |
|-----------------|-----------------|-------------------------------------------------|
| <code>in</code> | <code>bc</code> | Vector that contains imposed values at all DOFs |
|-----------------|-----------------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC ( int *dof\_type* = *NODE\_DOF*, int *dof* = 0 )** [inherited]

Update element matrix to impose bc by diagonalization technique.

Parameters

|                 |                       |                                                                                                                                                                                                                                                                                                                  |
|-----------------|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>dof_type</code> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE_FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT_FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE_FIELD</code>, DOFs are supported by sides</li> </ul> |
| <code>in</code> | <code>dof</code>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <code>dof</code> is handled in the system</li> </ul>                                                                                                |

**void LocalNodeVector ( Vect< T\_ > & *b* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|                 |                |                                                                                                                                                                                                                        |
|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>b</code> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NEE\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only yhe dega dof is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

Vector b is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & b, LocalVect< T\_, NSE\_ > & be )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
[inherited]

Localize [Element](#) Vector.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                                    |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF number <code>dof</code> is handled in the system</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> .              |

## Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer `_theElement`

**void SideVector ( const Vect< T\_ > & b )** [inherited]

Localize [Side](#) Vector.

## Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                                       |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [ default ]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> The resulting local vector can be accessed by attribute <code>ePrev</code> . |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( [Matrix](#)< [T\\_](#) > \* *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [PETScVect](#)< [T\\_](#) > & *b* )** [inherited]

Assemble element right-hand side vector into global one.

Parameters

|          |                                            |
|----------|--------------------------------------------|
| <i>b</i> | Reference to global right-hand side vector |
|----------|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [BMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                            |
|----------|------------------------------------------------------------|
| <i>A</i> | Global matrix stored as a <a href="#">BMatrix</a> instance |
|----------|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( [SkSMatrix](#)< [T\\_](#) > & *A* )** [inherited]

Assemble element matrix into global one.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.



Parameters

|     |                            |
|-----|----------------------------|
| $A$ | Reference to global matrix |
|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                               |
|----|-----|---------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|-----|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
| $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|----------|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< T\_ > & x, Vect< T\_ > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector to add ( <a href="#">Vect</a> instance)         |

**void AxbAssembly ( const Side & sd, const Vect< T\_ > & x, Vect< T\_ > & b )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real t setMaterialProperty ( const string & exp, const string & prop )** [inherited]

Define a material property by an algebraic expression.

## Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

## Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

#### 7.74.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.75 ODESolver Class Reference

To solve a system of ordinary differential equations.

### Public Member Functions

- [ODESolver](#) ()  
*Default constructor.*
- [ODESolver](#) ([TimeScheme](#) s, [real.t](#) time\_step=[theTimeStep](#), [real.t](#) final\_time=[theFinalTime](#), [size.t](#) nb\_eq=1)  
*Constructor using time discretization data.*
- [~ODESolver](#) ()  
*Destructor.*
- void [set](#) ([TimeScheme](#) s, [real.t](#) time\_step=[theTimeStep](#), [real.t](#) final\_time=[theFinalTime](#))  
*Define data of the differential equation or system.*
- void [setNbEq](#) ([size.t](#) nb\_eq)  
*Set the number of equations [Default: 1].*
- void [setCoef](#) ([real.t](#) a0, [real.t](#) a1, [real.t](#) a2, [real.t](#) f)  
*Define coefficients in the case of a scalar differential equation.*
- void [setCoef](#) (string a0, string a1, string a2, string f)  
*Define coefficients in the case of a scalar differential equation.*
- void [setF](#) (string F)  
*Set time derivative, given as an algebraic expression, for a nonlinear ODE.*
- void [setRK4RHS](#) ([real.t](#) f)  
*Set intermediate right-hand side vector for the Runge-Kutta method.*
- void [setRK4RHS](#) ([Vect](#)< [real.t](#) > &f)  
*Set intermediate right-hand side vector for the Runge-Kutta method.*
- void [setInitial](#) ([Vect](#)< [real.t](#) > &u)  
*Set initial condition for a first-order system of differential equations.*
- void [setInitial](#) ([Vect](#)< [real.t](#) > &u, [Vect](#)< [real.t](#) > &v)  
*Set initial condition for a second-order system of differential equations.*
- void [setInitialRHS](#) ([Vect](#)< [real.t](#) > &f)  
*Set initial RHS for a system of differential equations.*
- void [setInitial](#) ([real.t](#) u, [real.t](#) v)  
*Set initial condition for a second-order ordinary differential equation.*
- void [setInitial](#) ([real.t](#) u)  
*Set initial condition for a first-order ordinary differential equation.*
- void [setInitialRHS](#) ([real.t](#) f)  
*Set initial right-hand side for a single differential equation.*
- void [setMatrices](#) ([DMatrix](#)< [real.t](#) > &A0, [DMatrix](#)< [real.t](#) > &A1)  
*Define matrices for a system of first-order ODEs.*
- void [setMatrices](#) ([DMatrix](#)< [real.t](#) > &A0, [DMatrix](#)< [real.t](#) > &A1, [DMatrix](#)< [real.t](#) > &A2)  
*Define matrices for a system of second ODEs.*
- void [setRHS](#) ([Vect](#)< [real.t](#) > &b)  
*Set right-hand side vector for a system of ODE.*
- void [setRHS](#) ([real.t](#) f)  
*Set right-hand side for a linear ODE.*

- void `setRHS` (string f)  
*Set right-hand side value for a linear ODE.*
- void `setNewmarkParameters` (real.t beta, real.t gamma)  
*Define parameters for the Newmark scheme.*
- void `setConstantMatrix` ()  
*Say that matrix problem is constant.*
- void `setNonConstantMatrix` ()  
*Say that matrix problem is variable.*
- void `setLinearSolver` (Iteration s=DIRECT\_SOLVER, Preconditioner p=DIAG\_PREC)  
*Set linear solver data.*
- void `setVerbose` (int v=0)  
*Set verbosity parameter:*
- real.t `runOneTimeStep` ()  
*Run one time step.*
- void `run` (bool opt=false)  
*Run the time stepping procedure.*
- LinearSolver< real.t > & `getLSolver` ()  
*Return LinearSolver instance.*
- real.t `get` () const  
*Return solution in the case of a scalar equation.*

### 7.75.1 Detailed Description

To solve a system of ordinary differential equations.

The class `ODESolver` enables solving by a numerical scheme a system of ordinary differential equations taking one of the forms:

- A linear system of differential equations of the first-order:  
$$\mathbf{A}_1(t) \mathbf{u}'(t) + \mathbf{A}_0(t) \mathbf{u}(t) = \mathbf{f}(t)$$
- A linear system of differential equations of the second-order:  
$$\mathbf{A}_2(t) \mathbf{u}''(t) + \mathbf{A}_1(t) \mathbf{u}'(t) + \mathbf{A}_0(t) \mathbf{u}(t) = \mathbf{f}(t)$$
- A system of ordinary differential equations of the form:  
$$\mathbf{u}'(t) = \mathbf{f}(t, \mathbf{u}(t))$$

The following time integration schemes can be used:

- Forward Euler scheme (value: `FORWARD_EULER`) for first-order systems
- Backward Euler scheme (value: `BACKWARD_EULER`) for first-order linear systems
- Crank-Nicolson (value: `CRANK_NICOLSON`) for first-order linear systems
- Heun (value: `HEUN`) for first-order systems
- 2nd Order Adams-Bashforth (value: `AB2`) for first-order systems
- 4-th order Runge-Kutta (value: `RK4`) for first-order systems
- 2nd order Backward Differentiation Formula (value: `BDF2`) for linear first-order systems
- Newmark (value: `NEWMARK`) for linear second-order systems with constant matrices

### 7.75.2 Constructor & Destructor Documentation

**ODESolver** ( *TimeScheme* *s*, *real.t time\_step* = *theTimeStep*, *real.t final\_time* = *theFinalTime*, *size.t nb\_eq* = 1 )

Constructor using time discretization data.

Parameters

|    |                   |                                                                                                                                                                                            |
|----|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>s</i>          | Choice of the scheme: To be chosen in the enumerated variable <i>TimeScheme</i> (see the presentation of the class)                                                                        |
| in | <i>time_step</i>  | Value of the time step. This value will be modified if an adaptive method is used. The default value for this parameter is the value given by the global variable <code>theTimeStep</code> |
| in | <i>final_time</i> | Value of the final time (time starts at 0). The default value for this parameter is the value given by the global variable <code>theFinalTime</code>                                       |
| in | <i>nb_eq</i>      | Number of differential equations (size of the system) [Default: 1]                                                                                                                         |

### 7.75.3 Member Function Documentation

**void set ( TimeScheme *s*, real\_t *time\_step* = theTimeStep, real\_t *final\_time* = theFinalTime )**

Define data of the differential equation or system.

Parameters

|    |                   |                                                                                                                                                                                            |
|----|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>s</i>          | Choice of the scheme: To be chosen in the enumerated variable <i>TimeScheme</i> (see the presentation of the class)                                                                        |
| in | <i>time_step</i>  | Value of the time step. This value will be modified if an adaptive method is used. The default value for this parameter is the value given by the global variable <code>theTimeStep</code> |
| in | <i>final_time</i> | Value of the final time (time starts at 0). The default value for this parameter is the value given by the global variable <code>theFinalTime</code>                                       |

**void setNbEq ( size\_t *nb\_eq* )**

Set the number of equations [Default: 1].

This function is to be used if the default constructor was used

**void setCoef ( real\_t *a0*, real\_t *a1*, real\_t *a2*, real\_t *f* )**

Define coefficients in the case of a scalar differential equation.

This function enables giving coefficients of the differential equation as an algebraic expression of time *t* (see the function `fparse`)

Parameters

|    |           |                                    |
|----|-----------|------------------------------------|
| in | <i>a0</i> | Coefficient of the 0-th order term |
| in | <i>a1</i> | Coefficient of the 1-st order term |
| in | <i>a2</i> | Coefficient of the 2-nd order term |
| in | <i>f</i>  | Value of the right-hand side       |

Note

Naturally, the equation is of the first order if *a2*=0

**void setCoef ( string *a0*, string *a1*, string *a2*, string *f* )**

Define coefficients in the case of a scalar differential equation.



Parameters

|    |      |                                    |
|----|------|------------------------------------|
| in | $a0$ | Coefficient of the 0-th order term |
| in | $a1$ | Coefficient of the 1-st order term |
| in | $a2$ | Coefficient of the 2-nd order term |
| in | $f$  | Value of the right-hand side       |

Note

Naturally, the equation is of the first order if  $a2=0$

**void setF ( string  $F$  )**

Set time derivative, given as an algebraic expression, for a nonlinear ODE.

This function enables prescribing the value of the 1-st derivative for a 1st order ODE or the 2nd one for a 2nd-order ODE. It is to be used for nonlinear ODEs of the form  $y'(t) = f(t, y(t))$  or  $y''(t) = f(t, y(t), y'(t))$

In the case of a system of ODEs, this function can be called once for each equation, given in the order of the unknowns

**void setRK4RHS ( real.t  $f$  )**

Set intermediate right-hand side vector for the Runge-Kutta method.

Parameters

|    |     |  |
|----|-----|--|
| in | $f$ |  |
|----|-----|--|

**void setRK4RHS ( Vect< real.t > &  $f$  )**

Set intermediate right-hand side vector for the Runge-Kutta method.

Parameters

|    |     |                        |
|----|-----|------------------------|
| in | $f$ | right-hand side vector |
|----|-----|------------------------|

**void setInitial ( Vect< real.t > &  $u$  )**

Set initial condition for a first-order system of differential equations.

Parameters

|    |     |                                                     |
|----|-----|-----------------------------------------------------|
| in | $u$ | Vector containing initial condition for the unknown |
|----|-----|-----------------------------------------------------|

**void setInitial ( Vect< real.t > &  $u$ , Vect< real.t > &  $v$  )**

Set initial condition for a second-order system of differential equations.

Giving the right-hand side at initial time is sometimes required for high order methods like Runge-Kutta

Parameters

|    |     |                                                     |
|----|-----|-----------------------------------------------------|
| in | $u$ | Vector containing initial condition for the unknown |
|----|-----|-----------------------------------------------------|

|                 |                |                                                                            |
|-----------------|----------------|----------------------------------------------------------------------------|
| <code>in</code> | <code>v</code> | Vector containing initial condition for the time derivative of the unknown |
|-----------------|----------------|----------------------------------------------------------------------------|

**void setInitialRHS ( Vect< real\_t > &f )**

Set initial RHS for a system of differential equations.

Giving the right-hand side at initial time is sometimes required for high order methods like Runge-Kutta

Parameters

|                 |                |                                                                                                  |
|-----------------|----------------|--------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>f</code> | Vector containing right-hand side at initial time. This vector is helpful for high order methods |
|-----------------|----------------|--------------------------------------------------------------------------------------------------|

**void setInitial ( real\_t u, real\_t v )**

Set initial condition for a second-order ordinary differential equation.

Parameters

|                 |                |                                                          |
|-----------------|----------------|----------------------------------------------------------|
| <code>in</code> | <code>u</code> | Initial condition (unknown) value                        |
| <code>in</code> | <code>v</code> | Initial condition (time derivative of the unknown) value |

**void setInitial ( real\_t u )**

Set initial condition for a first-order ordinary differential equation.

Parameters

|                 |                |                                   |
|-----------------|----------------|-----------------------------------|
| <code>in</code> | <code>u</code> | Initial condition (unknown) value |
|-----------------|----------------|-----------------------------------|

**void setInitialRHS ( real\_t f )**

Set initial right-hand side for a single differential equation.

Parameters

|                 |                |                                                                                        |
|-----------------|----------------|----------------------------------------------------------------------------------------|
| <code>in</code> | <code>f</code> | Value of right-hand side at initial time. This value is helpful for high order methods |
|-----------------|----------------|----------------------------------------------------------------------------------------|

**void setMatrices ( DMatrix< real\_t > &A0, DMatrix< real\_t > &A1 )**

Define matrices for a system of first-order ODEs.

Matrices are given as references to class [DMatrix](#).

Parameters

|                 |                 |                                                                             |
|-----------------|-----------------|-----------------------------------------------------------------------------|
| <code>in</code> | <code>A0</code> | Reference to matrix in front of the 0-th order term (no time derivative)    |
| <code>in</code> | <code>A1</code> | Reference to matrix in front of the 1-st order term (first time derivative) |

Remarks

This function has to be called at each time step

**void setMatrices ( DMatrix< real.t > & A0, DMatrix< real.t > & A1, DMatrix< real.t > & A2 )**

Define matrices for a system of second ODEs.

Matrices are given as references to class [DMatrix](#).

Parameters

|    |    |                                                                              |
|----|----|------------------------------------------------------------------------------|
| in | A0 | Reference to matrix in front of the 0-th order term (no time derivative)     |
| in | A1 | Reference to matrix in front of the 1-st order term (first time derivative)  |
| in | A2 | Reference to matrix in front of the 2-nd order term (second time derivative) |

Remarks

This function has to be called at each time step

**void setRHS ( Vect< real.t > & b )**

Set right-hand side vector for a system of ODE.

Parameters

|    |   |                                                                                                                 |
|----|---|-----------------------------------------------------------------------------------------------------------------|
| in | b | <a href="#">Vect</a> instance containing right-hand side for a linear system of ordinary differential equations |
|----|---|-----------------------------------------------------------------------------------------------------------------|

**void setRHS ( real.t f )**

Set right-hand side for a linear ODE.

Parameters

|    |   |                                                                          |
|----|---|--------------------------------------------------------------------------|
| in | f | Value of the right-hand side for a linear ordinary differential equation |
|----|---|--------------------------------------------------------------------------|

**void setNewmarkParameters ( real.t beta, real.t gamma )**

Define parameters for the Newmark scheme.

Parameters

|    |       |                                |
|----|-------|--------------------------------|
| in | beta  | Parameter beta [Default: 0.25] |
| in | gamma | Parameter gamma [Default: 0.5] |

**void setConstantMatrix ( )**

Say that matrix problem is constant.

This is useful if the linear system is solved by a factorization method but has no effect otherwise

**void setNonConstantMatrix ( )**

Say that matrix problem is variable.

This is useful if the linear system is solved by a factorization method but has no effect otherwise

**void setLinearSolver ( Iteration  $s$  = DIRECT\_SOLVER, Preconditioner  $p$  = DIAG\_PREC )**

Set linear solver data.

## Parameters

|    |   |                                                                                                                                                                                                                   |
|----|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | s | Solver identification parameter. To be chosen in the enumeration variable Iteration:<br>DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER<br>[Default: DIRECT_SOLVER] |
| in | p | Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner:<br>IDENT_PREC, DIAG_PREC, ILU_PREC [Default: DIAG_PREC]                                                         |

## Note

The argument *p* has no effect if the solver is DIRECT\_SOLVER

**void setVerbose ( int *v* = 0 )**

Set verbosity parameter:

- = 0, No output
- = 1, Print step label and time value
- = 2, Print step label, time value, time step and integration scheme

**real\_t runOneTimeStep ( )**

Run one time step.

## Returns

Value of new time step if this one is updated

**void run ( bool *opt* = false )**

Run the time stepping procedure.

## Parameters

|    |            |                                                                                                      |
|----|------------|------------------------------------------------------------------------------------------------------|
| in | <i>opt</i> | Flag to say if problem matrix is constant while time stepping (true) or not (Default value is false) |
|----|------------|------------------------------------------------------------------------------------------------------|

## Note

This argument is not used if the time stepping scheme is explicit

## 7.76 Partition Class Reference

To partition a finite element mesh into balanced submeshes.

## Public Member Functions

- **Partition** ()  
*Default constructor.*
- **Partition** (**Mesh** &mesh, size\_t n, int verb=0)  
*Constructor to partition a mesh into submeshes.*
- **Partition** (**Mesh** &mesh, int n, vector< int > &epart, int verb=0)  
*Constructor using already created submeshes.*
- **~Partition** ()  
*Destructor.*
- size\_t **getNbSubMeshes** () const  
*Return number of submeshes.*
- size\_t **getNbNodes** (size\_t i) const  
*Return number of nodes in given submesh.*
- size\_t **getNbElements** (size\_t i) const  
*Return number of elements in given submesh.*
- **Mesh** \* **getMesh** ()  
*Return the global **Mesh** instance.*
- **Mesh** \* **getMesh** (size\_t i)  
*Return the submesh of label *i**
- size\_t **getNodeLabelInSubMesh** (size\_t sm, size\_t label) const  
*Return node label in subdomain by giving its label in initial mesh.*
- size\_t **getElementLabelInSubMesh** (size\_t sm, size\_t label) const  
*Return element label in subdomain by giving its label in initial mesh.*
- size\_t **getNodeLabelInMesh** (size\_t sm, size\_t label) const  
*Return node label in initial mesh by giving its label in submesh.*
- size\_t **getElementLabelInMesh** (size\_t sm, size\_t label) const  
*Return element label in initial mesh by giving its label in submesh.*
- size\_t **getNbInterfaceSides** (size\_t sm) const  
*Return Number of interface sides for a given sub-mesh.*
- size\_t **getSubMesh** (size\_t sm, size\_t i) const  
*Return index of submesh that contains the *i*-th side label in sub-mesh *sm**
- **Mesh** & **getSubMesh** (size\_t i) const  
*Return reference to submesh.*
- size\_t **getFirstSideLabel** (size\_t sm, size\_t i) const  
*Return *i*-th side label in a given submesh.*
- size\_t **getSecondSideLabel** (size\_t sm, size\_t i) const  
*Return side label in the neighbouring submesh corresponding to *i*-th side label in sub-mesh *sm**
- int **getNbConnectInSubMesh** (int n, int s) const  
*Get number of connected nodes in a submesh.*
- int **getNbConnectOutSubMesh** (int n, int s) const  
*Get number of connected nodes out of a submesh.*
- void **put** (size\_t n, string file) const  
*Save a submesh in file.*
- void **setVerbose** (int verb)  
*Set Message Level.*
- void **set** (**Mesh** &mesh, size\_t n)  
*Set **Mesh** instance.*

## Friends

- ostream & **operator<<** (ostream &s, const **Partition** &p)  
*Output class information.*

### 7.76.1 Detailed Description

To partition a finite element mesh into balanced submeshes.

Class **Partition** enables partitioning a given mesh into a given number of submeshes with a minimal connectivity. **Partition** uses the well known **metis** library that is included in the **OFELI** library. A more detailed description of **metis** can be found in the web site:

[http://www.csit.fsu.edu/~burkardt/c\\_src/metis/metis.html](http://www.csit.fsu.edu/~burkardt/c_src/metis/metis.html)

### 7.76.2 Constructor & Destructor Documentation

**Partition ( Mesh & mesh, size\_t n, int verb = 0 )**

Constructor to partition a mesh into submeshes.

Parameters

|    |             |                                  |
|----|-------------|----------------------------------|
| in | <i>mesh</i> | <b>Mesh</b> instance             |
| in | <i>n</i>    | Number of submeshes              |
| in | <i>verb</i> | Verbosity parameter [Default: 0] |

**Partition ( Mesh & mesh, int n, vector< int > & epart, int verb = 0 )**

Constructor using already created submeshes.

Parameters

|    |              |                                                                              |
|----|--------------|------------------------------------------------------------------------------|
| in | <i>mesh</i>  | <b>Mesh</b> instance                                                         |
| in | <i>n</i>     | Number of submeshes                                                          |
| in | <i>epart</i> | Vector containing for each element its submesh label (Running from 0 to n-1) |
| in | <i>verb</i>  | Verbosity parameter [Default: 0]                                             |

### 7.76.3 Member Function Documentation

**size\_t getNodeLabelInSubMesh ( size\_t sm, size\_t label ) const**

Return node label in subdomain by giving its label in initial mesh.

Parameters

|    |              |                               |
|----|--------------|-------------------------------|
| in | <i>sm</i>    | Label of submesh              |
| in | <i>label</i> | Label of node in initial mesh |

**size\_t getNodeLabelInMesh ( size\_t sm, size\_t label ) const**

Return node label in initial mesh by giving its label in submesh.

Parameters

|                 |                    |                            |
|-----------------|--------------------|----------------------------|
| <code>in</code> | <code>sm</code>    | Label of submesh           |
| <code>in</code> | <code>label</code> | <a href="#">Node</a> label |

**size\_t getSubMesh ( size\_t *sm*, size\_t *i* ) const**

Return index of submesh that contains the *i*-th side label in sub-mesh *sm*

Parameters

|                 |                 |                            |
|-----------------|-----------------|----------------------------|
| <code>in</code> | <code>sm</code> | Submesh index              |
| <code>in</code> | <code>i</code>  | <a href="#">Side</a> label |

Returns

**Mesh& getSubMesh ( size\_t *i* ) const**

Return reference to submesh.

Parameters

|                 |                |               |
|-----------------|----------------|---------------|
| <code>in</code> | <code>i</code> | Submesh index |
|-----------------|----------------|---------------|

Returns

Reference to corresponding [Mesh](#) instance

**size\_t getFirstSideLabel ( size\_t *sm*, size\_t *i* ) const**

Return *i*-th side label in a given submesh.

Parameters

|                 |                 |                  |
|-----------------|-----------------|------------------|
| <code>in</code> | <code>sm</code> | Index of submesh |
| <code>in</code> | <code>i</code>  | Label of side    |

**size\_t getSecondSideLabel ( size\_t *sm*, size\_t *i* ) const**

Return side label in the neighbouring submesh corresponding to *i*-th side label in sub-mesh *sm*

Parameters

|                 |                 |                            |
|-----------------|-----------------|----------------------------|
| <code>in</code> | <code>sm</code> | Label of submesh           |
| <code>in</code> | <code>i</code>  | <a href="#">Side</a> label |

**int getNbConnectInSubMesh ( int *n*, int *s* ) const**

Get number of connected nodes in a submesh.

Parameters

|                 |                |                                                 |
|-----------------|----------------|-------------------------------------------------|
| <code>in</code> | <code>n</code> | Label of node for which connections are counted |
| <code>in</code> | <code>s</code> | Label of submesh (starting from 0)              |

**int getNbConnectOutSubMesh ( int *n*, int *s* ) const**

Get number of connected nodes out of a submesh.



Parameters

|    |     |                                                 |
|----|-----|-------------------------------------------------|
| in | $n$ | Label of node for which connections are counted |
| in | $s$ | Label of submesh (starting from 0)              |

**void put ( size\_t  $n$ , string  $file$  ) const**

Save a submesh in file.

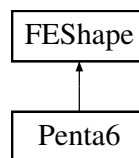
Parameters

|    |        |                                        |
|----|--------|----------------------------------------|
| in | $n$    | Label of submesh                       |
| in | $file$ | Name of file in which submesh is saved |

## 7.77 Penta6 Class Reference

Defines a 6-node pentahedral finite element using  $P_1$  interpolation in local coordinates ( $s.-x, s.y$ ) and  $Q_1$  isoparametric interpolation in local coordinates ( $s.x, s.z$ ) and ( $s.y, s.z$ ).

Inheritance diagram for Penta6:



### Public Member Functions

- [Penta6](#) ()  
*Default Constructor.*
- [Penta6](#) (const [Element](#) \*element)  
*Constructor when data of [Element](#)  $el$  are given.*
- [~Penta6](#) ()  
*Destructor.*
- void [set](#) (const [Element](#) \*el)  
*Choose element by giving its pointer.*
- void [setLocal](#) (const [Point](#)< [real\\_t](#) > &s)  
*Initialize local point coordinates in element.*
- [Point](#)< [real\\_t](#) > [DSh](#) (size\_t i) const  
*Return derivatives of shape function of node  $i$  at a given point.*
- [real\\_t](#) [getMaxEdgeLength](#) () const  
*Return Maximum length of pentahedron edges.*
- [real\\_t](#) [getMinEdgeLength](#) () const  
*Return Mimimum length of pentahedron edges.*
- [real\\_t](#) [Sh](#) (size\_t i) const  
*Return shape function of node  $i$  at given point.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node  $i$  at a given point  $s$ .*
- [real\\_t](#) [getDet](#) () const

*Return determinant of jacobian.*

- `Point< real.t > getCenter () const`

*Return coordinates of center of element.*

- `Point< real.t > getLocalPoint () const`

*Localize a point in the element.*

- `Point< real.t > getLocalPoint (const Point< real.t > &s) const`

*Localize a point in the element.*

### 7.77.1 Detailed Description

Defines a 6-node pentahedral finite element using  $P_1$  interpolation in local coordinates  $(s.x, s.y)$  and  $Q_1$  isoparametric interpolation in local coordinates  $(s.x, s.z)$  and  $(s.y, s.z)$ .

The reference element is the cartesian product of the standard reference triangle with the line  $[-1, 1]$ . The nodes are ordered as follows: **Node 1** in reference element is at  $s=(1,0,0)$  **Node 2** in reference element is at  $s=(0,1,0)$  **Node 3** in reference element is at  $s=(0,0,0)$  **Node 4** in reference element is at  $s=(1,0,1)$  **Node 5** in reference element is at  $s=(0,1,1)$  **Node 6** in reference element is at  $s=(0,0,1)$

The user must take care to the fact that determinant of jacobian and other quantities depend on the point in the reference element where they are calculated. For this, before any utilization of shape functions or jacobian, function `setLocal()` must be invoked.

### 7.77.2 Constructor & Destructor Documentation

**Penta6 ( const Element \* element )**

Constructor when data of `Element` e1 are given.

Parameters

|    |         |                                 |
|----|---------|---------------------------------|
| in | element | Pointer to <code>Element</code> |
|----|---------|---------------------------------|

### 7.77.3 Member Function Documentation

**void setLocal ( const Point< real.t > & s )**

Initialize local point coordinates in element.

Parameters

|    |   |                                                                                                                                                                                   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | s | <code>Point</code> in the reference element This function computes jacobian, shape functions and their partial derivatives at s. Other member functions only return these values. |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Point<real.t> DSh ( size.t i ) const**

Return derivatives of shape function of node i at a given point.

Member function `setLocal()` must have been called before in order to calculate relevant quantities.

**real.t Sh ( size.t i, Point< real.t > s ) const** [inherited]

Calculate shape function of node i at a given point s.

Parameters

|    |          |                                                                                       |
|----|----------|---------------------------------------------------------------------------------------|
| in | <i>i</i> | Local node label                                                                      |
| in | <i>s</i> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.78 PETScMatrix< T\_ > Class Template Reference

To handle matrices in sparse storage format using the Petsc library.

### Public Member Functions

- [PETScMatrix](#) ()  
*Default constructor.*
- [PETScMatrix](#) (size\_t nr, size\_t nc)  
*Constructor that initializes current instance as a dense matrix.*
- [PETScMatrix](#) (size\_t size)  
*Constructor that initializes current instance as a dense matrix.*
- [PETScMatrix](#) ([Mesh](#) &mesh, size\_t dof=0)  
*Constructor using a [Mesh](#) instance.*
- [PETScMatrix](#) (const vector< std::pair< size\_t, size\_t > > &I, int opt=1)  
*Constructor for a square matrix using non zero row and column indices.*
- [PETScMatrix](#) (const [PETScMatrix](#) &m)  
*Copy constructor.*
- [~PETScMatrix](#) (void)  
*Destructor.*
- void [Identity](#) ()  
*Define matrix as identity matrix.*
- void [Diagonal](#) ()  
*Define matrix as a diagonal one.*
- void [Diagonal](#) (const T\_ &a)  
*Define matrix as a diagonal one with diagonal entries equal to a*

- void [setAIJ](#) (const vector< int > &nnz)
- void [setAIJ\\_MPI](#) (const vector< int > &diag\_nnz, const vector< int > &off\_nnz)
- void [setMesh](#) ([Mesh](#) &mesh, size\_t dof=0)  
*Determine mesh graph and initialize matrix.*
- void [setPartition](#) ([Partition](#) &p)  
*Set a [Partition](#) instance in the class.*
- void [setRank](#) (int np, int r=0)  
*Set number of processors and processor rank.*
- void [setOneDOF](#) ()  
*Activate 1-DOF per node option.*
- void [setSides](#) ()  
*Activate Sides option.*
- void [setSymmetric](#) ()  
*Set matrix as a symmetric one.*
- void [DiagPrescribe](#) ([PETScVect](#)< T\_ > &b, const [PETScVect](#)< T\_ > &u)  
*Impose by a diagonal method an essential boundary condition using the [Mesh](#) instance provided by the constructor.*
- void [setSize](#) (size\_t size)  
*Set size of matrix (case where it's a square matrix).*
- void [setSize](#) (size\_t nr, size\_t nc)  
*Set size (number of rows) of matrix.*
- void [getRange](#) (int istart, int iend)  
*Return the range of matrix rows owned by this processor.*
- void [setGraph](#) (const vector< std::pair< size\_t, size\_t > > &I, int opt=1)  
*Set graph of matrix by giving a vector of its nonzero entries.*
- T\_ [operator\(\)](#) (size\_t i, size\_t j) const  
*Operator ()*
- size\_t [getNbRows](#) () const  
*Return number of matrix rows.*
- size\_t [getNbColumns](#) () const  
*Return number of matrix columns.*
- size\_t [getLength](#) () const  
*Return length of matrix.*
- void [getMesh](#) ([Mesh](#) &mesh)  
*Get [Mesh](#) instance whose reference will be stored in current instance of [PETScMatrix](#).*
- void [Mult](#) (const [PETScVect](#)< T\_ > &x, [PETScVect](#)< T\_ > &y) const  
*Multiply matrix by vector and save in another one.*
- void [MultAdd](#) (const [PETScVect](#)< T\_ > &x, [PETScVect](#)< T\_ > &y) const  
*Multiply matrix by vector x and add to y.*
- void [MultAdd](#) (T\_ a, const [PETScVect](#)< T\_ > &x, [PETScVect](#)< T\_ > &y) const  
*Multiply matrix by vector a\*x and add to y.*
- void [set](#) (size\_t i, size\_t j, const T\_ &a)  
*Assign a value to an entry of the matrix.*
- void [add](#) (size\_t i, size\_t j, const T\_ &a)  
*Add a value to an entry of the matrix.*
- void [set](#) (vector< int > &ir, vector< int > &ic, vector< T\_ > &val)  
*Assign values to a portion of the matrix.*

- void `operator=` (const T\_ &a)  
*Operator =*
- void `clear` ()  
*Set all matrix entries to zero.*
- void `Laplace1D` (real\_t h, bool mpi=false)  
*Sets the matrix as the one for the Laplace equation in 1-D.*
- void `Laplace2D` (size\_t nx, size\_t ny, bool mpi=false)  
*Sets the matrix as the one for the Laplace equation in 2-D.*
- int `solve` (PETScVect< T\_ > &b)  
*Solve the linear system of equations.*
- int `solve` (const PETScVect< T\_ > &b, PETScVect< T\_ > &x)  
*Solve the linear system of equations.*
- void `setSolver` (string solver, string prec, real\_t toler=1.e-12, int max\_it=1000)  
*Choose solver and preconditioner for an iterative procedure.*
- T\_ \* `get` () const  
*Return C-Array.*
- T\_ `get` (size\_t i, size\_t j) const  
*Return entry (i, j) of matrix if this one is stored, 0 otherwise.*
- `operator Mat` () const  
*Casting operator.*
- PetscReal `getNorm1` () const  
*Get 1-norm of matrix.*
- PetscReal `getFrobeniusNorm` () const  
*Get Frobenius norm of matrix.*
- PetscReal `getNormMax` () const  
*Get infinity norm of matrix.*
- void `Assembly` (const Element &el, T\_ \*a)  
*Assembly of element matrix into global matrix.*
- void `Assembly` (const Side &sd, T\_ \*a)  
*Assembly of side matrix into global matrix.*
- void `setAssembly` ()  
*Matrix assembly.*
- void `setMPI` ()  
*Activate MPI option.*

### 7.78.1 Detailed Description

`template<class T_>class OFELI::PETScMatrix< T_ >`

To handle matrices in sparse storage format using the Petsc library.

Warning

This class is available only when `OFELI` has been installed with Petsc.

## Template Parameters

|           |                                                 |
|-----------|-------------------------------------------------|
| <i>T_</i> | Data type (double, float, complex<double>, ...) |
|-----------|-------------------------------------------------|

## 7.78.2 Constructor &amp; Destructor Documentation

**PETScMatrix ( )**

Default constructor.

Initialize a zero-dimension matrix

**PETScMatrix ( size\_t *nr*, size\_t *nc* )**

Constructor that initializes current instance as a dense matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <i>in</i> | <i>nr</i> | Number of matrix rows.    |
| <i>in</i> | <i>nc</i> | Number of matrix columns. |

**PETScMatrix ( size\_t *size* )**

Constructor that initializes current instance as a dense matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|           |             |                                      |
|-----------|-------------|--------------------------------------|
| <i>in</i> | <i>size</i> | Number of matrix rows (and columns). |
|-----------|-------------|--------------------------------------|

**PETScMatrix ( Mesh & *mesh*, size\_t *dof* = 0 )**

Constructor using a [Mesh](#) instance.

Parameters

|           |             |                                                                                                                                                                                                                                             |
|-----------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>mesh</i> | <a href="#">Mesh</a> instance from which matrix graph is extracted.                                                                                                                                                                         |
| <i>in</i> | <i>dof</i>  | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |

**PETScMatrix ( const vector< std::pair< size\_t, size\_t > > & *I*, int *opt* = 1 )**

Constructor for a square matrix using non zero row and column indices.

Parameters

|           |            |                                                                                                                                                                                              |
|-----------|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>I</i>   | Vector containing pairs of row and column indices                                                                                                                                            |
| <i>in</i> | <i>opt</i> | Flag indicating if vectors <i>I</i> is cleaned and ordered (opt=1) or not (opt=0). In the latter case, this vector can have the same contents more than once and are not necessarily ordered |

## 7.78.3 Member Function Documentation

**void setAIJ ( const vector< int > & *nnz* )**

Parameters

|           |            |  |
|-----------|------------|--|
| <i>in</i> | <i>nnz</i> |  |
|-----------|------------|--|

**void setAIJ\_MPI ( const vector< int > & *diag\_nnz*, const vector< int > & *off\_nnz* )**

Parameters

|           |                 |  |
|-----------|-----------------|--|
| <i>in</i> | <i>diag_nnz</i> |  |
| <i>in</i> | <i>off_nnz</i>  |  |

**void setMesh ( Mesh & *mesh*, size\_t *dof* = 0 )**

Determine mesh graph and initialize matrix.

This member function is called by constructor with the same arguments

Parameters

|           |             |                                                                                                                                                                                                                                             |
|-----------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>in</i> | <i>mesh</i> | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| <i>in</i> | <i>dof</i>  | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |

**void setPartition ( Partition & *p* )**

Set a [Partition](#) instance in the class.

This member function is to be used when parallel computing is considered.

Parameters

|           |          |                                                 |
|-----------|----------|-------------------------------------------------|
| <i>in</i> | <i>p</i> | Reference to <a href="#">Partition</a> instance |
|-----------|----------|-------------------------------------------------|

**void setRank ( int *np*, int *r* = 0 )**

Set number of processors and processor rank.

Parameters

|           |           |                                       |
|-----------|-----------|---------------------------------------|
| <i>in</i> | <i>np</i> | Total number of processors.           |
| <i>in</i> | <i>r</i>  | Rank of current processor [Default: 0 |

Warning

If this member function is not called, only one processor is used and then sequential computing is involved.

**void DiagPrescribe ( PETScVect< T\_ > & *b*, const PETScVect< T\_ > & *u* )**

Impose by a diagonal method an essential boundary condition using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |          |                                                                                                       |
|--------|----------|-------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">PETScVect</a> instance that contains right-hand side.                                     |
| in     | <i>u</i> | <a href="#">PETScVect</a> instance that contains imposed values at DOFs where they are to be imposed. |

**void setSize ( size\_t size )**

Set size of matrix (case where it's a square matrix).

Parameters

|    |             |                             |
|----|-------------|-----------------------------|
| in | <i>size</i> | Number of rows and columns. |
|----|-------------|-----------------------------|

**void setSize ( size\_t nr, size\_t nc )**

Set size (number of rows) of matrix.

Parameters

|    |           |                   |
|----|-----------|-------------------|
| in | <i>nr</i> | Number of rows    |
| in | <i>nc</i> | Number of columns |

**void getRange ( int istart, int iend )**

Return the range of matrix rows owned by this processor.

Parameters

|     |               |                              |
|-----|---------------|------------------------------|
| out | <i>istart</i> | Index of the first local row |
| out | <i>iend</i>   | Index of the last local row  |

**void setGraph ( const vector< std::pair< size\_t, size\_t > > & I, int opt = 1 )**

Set graph of matrix by giving a vector of its nonzero entries.

Parameters

|    |            |                                                                                                                                                                                               |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>I</i>   | Vector containing pairs of row and column indices                                                                                                                                             |
| in | <i>opt</i> | Flag indicating if vector I is cleaned and ordered (opt=1: default) or not (opt=0). In the latter case, this vector can have the same contents more than once and are not necessarily ordered |

**T\_ operator() ( size\_t i, size\_t j ) const**

Operator ( )

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

**size\_t getLength ( ) const**

Return length of matrix.

The length is the total number of stored elements in the matrix



**void Mult ( const PETScVect< T\_ > & *x*, PETScVect< T\_ > & *y* ) const**

Multiply matrix by vector and save in another one.

Parameters

|            |          |                                            |
|------------|----------|--------------------------------------------|
| <b>in</b>  | <i>x</i> | Vector to multiply by matrix               |
| <b>out</b> | <i>y</i> | Vector that contains on output the result. |

**void MultAdd ( const PETScVect< T\_ > & *x*, PETScVect< T\_ > & *y* ) const**

Multiply matrix by vector *x* and add to *y*.

Parameters

|            |          |                                                                      |
|------------|----------|----------------------------------------------------------------------|
| <b>in</b>  | <i>x</i> | Vector to multiply by matrix                                         |
| <b>out</b> | <i>y</i> | Vector to add to the result. <i>y</i> contains on output the result. |

**void MultAdd ( T\_ *a*, const PETScVect< T\_ > & *x*, PETScVect< T\_ > & *y* ) const**

Multiply matrix by vector *a*\**x* and add to *y*.

Parameters

|            |          |                                                                      |
|------------|----------|----------------------------------------------------------------------|
| <b>in</b>  | <i>a</i> | Constant to multiply by matrix                                       |
| <b>in</b>  | <i>x</i> | Vector to multiply by matrix                                         |
| <b>out</b> | <i>y</i> | Vector to add to the result. <i>y</i> contains on output the result. |

**void set ( size\_t *i*, size\_t *j*, const T\_ & *a* )**

Assign a value to an entry of the matrix.

Parameters

|           |          |                                                     |
|-----------|----------|-----------------------------------------------------|
| <b>in</b> | <i>i</i> | Row index                                           |
| <b>in</b> | <i>j</i> | Column index                                        |
| <b>in</b> | <i>a</i> | Value to assign to <i>a</i> ( <i>i</i> , <i>j</i> ) |

**void add ( size\_t *i*, size\_t *j*, const T\_ & *a* )**

Add a value to an entry of the matrix.

Parameters

|           |          |                                                           |
|-----------|----------|-----------------------------------------------------------|
| <b>in</b> | <i>i</i> | Row index                                                 |
| <b>in</b> | <i>j</i> | Column index                                              |
| <b>in</b> | <i>a</i> | Constant value to add to <i>a</i> ( <i>i</i> , <i>j</i> ) |

**void set ( vector< int > & *ir*, vector< int > & *ic*, vector< T\_ > & *val* )**

Assign values to a portion of the matrix.

Parameters

|           |            |                                                               |
|-----------|------------|---------------------------------------------------------------|
| <b>in</b> | <i>ir</i>  | Vector of row indexes to assign (instance of class vector)    |
| <b>in</b> | <i>ic</i>  | Vector of column indexes to assign (instance of class vector) |
| <b>in</b> | <i>val</i> | Vector of values to assign (instance of class vector)         |

**void operator= ( const T\_ & a )**

Operator =

Assign constant value a to matrix diagonal entries

**void Laplace1D ( real\_t h, bool mpi = false )**

Sets the matrix as the one for the Laplace equation in 1-D.

The matrix is initialized as the one resulting from  $P_1$  finite element discretization of the classical elliptic operator  $-u'' = f$  with homogeneous Dirichlet boundary conditions

Remarks

This function is available for real valued matrices only.

Parameters

|    |            |                                                                                         |
|----|------------|-----------------------------------------------------------------------------------------|
| in | <i>h</i>   | Mesh size (assumed constant)                                                            |
| in | <i>mpi</i> | true if MPI is used for parallel computing, false if not (sequential), [Default: false] |

**void Laplace2D ( size\_t nx, size\_t ny, bool mpi = false )**

Sets the matrix as the one for the Laplace equation in 2-D.

The matrix is initialized as the one resulting from  $P_1$  finite element discretization of the classical elliptic operator  $-\Delta u = f$  with homogeneous Dirichlet boundary conditions

Remarks

This function is available for real valued matrices only.

Parameters

|    |            |                                                                                         |
|----|------------|-----------------------------------------------------------------------------------------|
| in | <i>nx</i>  | Number of unknowns in the x-direction                                                   |
| in | <i>ny</i>  | Number of unknowns in the y-direction                                                   |
| in | <i>mpi</i> | true if MPI is used for parallel computing, false if not (sequential), [Default: false] |

**int solve ( PETScVect< T\_ > & b )**

Solve the linear system of equations.

The default parameters are: the Conjugate Gradient method and the Jacobi method for preconditioner. To change these values, call function setSolver before this function

Parameters

|        |          |                                                                      |
|--------|----------|----------------------------------------------------------------------|
| in,out | <i>b</i> | Vector that contains right-hand side on input and solution on output |
|--------|----------|----------------------------------------------------------------------|

Returns

Number of actual performed iterations

**int solve ( const PETScVect< T\_ > & b, PETScVect< T\_ > & x )**

Solve the linear system of equations.

The default parameters are: the Conjugate Gradient method and the Jacobi method for preconditioner. To change these values, call function setSolver before this function

Parameters

|            |     |                                            |
|------------|-----|--------------------------------------------|
| <b>in</b>  | $b$ | Vector that contains right-hand side       |
| <b>out</b> | $x$ | Vector that contains the obtained solution |

Returns

Number of actual performed iterations

**void setSolver ( string *solver*, string *prec*, real\_t *toler* = 1. e- 12, int *max\_it* = 1000 )**

Choose solver and preconditioner for an iterative procedure.

## Parameters

|    |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                  |
|----|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>solver</i> | <p>Option to choose iterative solver among the macros (see PETSc documentation for more details):</p> <ul style="list-style-type: none"> <li>• KSPRICHARDSON: The Richardson iterative method (Default damping parameter is 1.0)</li> <li>• KSPCHEBYSHEV: The Chebyshev iterative method</li> <li>• KSPCG: The conjugate gradient method [Default]</li> <li>• KSPCGNE: The CG method for normal equations (without explicitly forming the product <math>A^T A</math>)</li> <li>• KSPGMRES: The GMRES iterative method (see A Generalized Minimal Residual Algorithm for Solving Nonsymmetric Linear Systems. Y. Saad and M. H. Schultz, SIAM J. Sci. Stat. Comput. Vol. 7, No. 3, July 1986, pp. 856-869)</li> <li>• KSPFGMRES: The Flexible GMRES method (with restart)</li> <li>• KSPLGMRES: The 'augmented' standard GMRES method where the subspace uses approximations to the error from previous restart cycles</li> <li>• KSPTQMR: A variant of QMR (quasi minimal residual) developed by Tony Chan</li> <li>• KSPBCGS: The BiCGStab (Stabilized version of BiConjugate Gradient Squared) method</li> <li>• KSPIBCGS: The IBiCGStab (Improved Stabilized version of BiConjugate Gradient Squared) method in an alternative form to have only a single global reduction operation instead of the usual 3 (or 4)</li> <li>• KSPFBCGS: The flexible BiCGStab method.</li> <li>• KSPCGS: The CGS (Conjugate Gradient Squared) method</li> <li>• KSPTFQMR: A transpose free QMR (quasi minimal residual)</li> <li>• KSPCR: The conjugate residuals method</li> <li>• KSPLSQR: The LSQR method</li> <li>• KSPBICG: The Biconjugate gradient method (similar to running the conjugate gradient on the normal equations)</li> <li>• KSPMINRES: The MINRES (Minimum Residual) method</li> <li>• KSPSYMLQ: The SYMLQ method</li> <li>• KSPGCR: The Generalized Conjugate Residual method</li> </ul> |
| in | <i>prec</i>   | <p>Option to choose preconditioner in an enumerated variable</p> <ul style="list-style-type: none"> <li>• PCJACOBI: [Default] Jacobi (<i>i.e.</i> diagonal scaling) preconditioning</li> <li>• PCBJACOBI: Block Jacobi preconditioning, each block is (approximately) solved with its own KSP object</li> <li>• PCSOR: (S)SOR (successive over relaxation, Gauss-Seidel) preconditioning</li> <li>• PCEISENSTAT: An implementation of SSOR (symmetric successive over relaxation, symmetric Gauss-Seidel) preconditioning that incorporates Eisenstat's trick to reduce the</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |

|    |               |                                                      |
|----|---------------|------------------------------------------------------|
| in | <i>toler</i>  | Tolerance for convergence [Default: 1.e-12]          |
| in | <i>max_it</i> | Maximum number of allowed iterations [Default: 1000] |

**T\_\* get ( ) const**

Return C-Array.

Non zero terms of matrix is stored row by row.

**T\_ get ( size\_t i, size\_t j ) const**

Return entry (i, j) of matrix if this one is stored, 0 otherwise.

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

**operator Mat ( ) const**

Casting operator.

This member functions enables casting an instance of class [PETScMatrix](#) into the Petsc matrix type Mat. This is useful when one wants to use any Petsc function that is not available in the wrapper (class [PETScWrapper](#)) or [PETScMatrix](#).

**void Assembly ( const Element & el, T\_\* a )**

Assembly of element matrix into global matrix.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Reference to element instance               |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Side & sd, T\_\* a )**

Assembly of side matrix into global matrix.

Parameters

|    |           |                                          |
|----|-----------|------------------------------------------|
| in | <i>sd</i> | Reference to side instance               |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array |

**void setAssembly ( )**

[Matrix](#) assembly.

This function assembles matrix (begins and ends)

## 7.79 PETScVect< T\_ > Class Template Reference

To handle general purpose vectors using Petsc.

## Public Member Functions

- **PETScVect** ()  
*Default Constructor. Initialize a zero-length vector.*
- **PETScVect** (size\_t n)  
*Constructor setting vector size.*
- **PETScVect** (size\_t nx, size\_t ny)  
*Constructor of a 2-D index vector.*
- **PETScVect** (size\_t nx, size\_t ny, size\_t nz)  
*Constructor of a 3-D index vector.*
- **PETScVect** (size\_t n, T\_ \*x)  
*Create an instance of class **PETScVect** as an image of a C/C++ array.*
- **PETScVect** (MPI\_Comm comm, size\_t n)  
*Constructor of a MPI vector using its global size.*
- **PETScVect** (Mesh &m, int nb\_dof=0, int dof\_type=NODE\_FIELD)  
*Constructor with a mesh instance.*
- **PETScVect** (Mesh &m, string name, real\_t t=0.0, int nb\_dof=0, int dof\_type=NODE\_FIELD)  
*Constructor with a mesh instance giving name and time for vector.*
- **PETScVect** (const PETScVect< T\_ > &v, const PETScVect< T\_ > &bc)  
*Constructor using boundary conditions.*
- **PETScVect** (const PETScVect< T\_ > &v, size\_t nb\_dof, size\_t first\_dof)  
*Constructor to select some components of a given vector.*
- **PETScVect** (const PETScVect< T\_ > &v)  
*Copy constructor.*
- **PETScVect** (const PETScVect< T\_ > &v, size\_t n)  
*Constructor to select one component from a given 2 or 3-component vector.*
- **PETScVect** (size\_t d, const PETScVect< T\_ > &v, const string &name="")  
*Constructor that extracts some degrees of freedom (components) from given instance of **PETScVect**.*
- **~PETScVect** ()  
*Destructor.*
- void **set** (const T\_ \*v, size\_t n)  
*Initialize vector with a c-array.*
- void **setMPI** (MPI\_Comm comm, size\_t n, size\_t N)  
*Initialize a local vector using MPI.*
- void **select** (const PETScVect< T\_ > &v, size\_t nb\_dof=0, size\_t first\_dof=1)  
*Initialize vector with another **PETScVect** instance.*
- void **set** (const string &exp, size\_t dof=1)  
*Initialize vector with an algebraic expression.*
- void **set** (const Mesh &ms, const string &exp, size\_t dof=1)  
*Initialize vector with an algebraic expression with providing mesh data.*
- void **set** (const PETScVect< real\_t > &x, const string &exp)  
*Initialize vector with an algebraic expression.*
- void **setMesh** (Mesh &m, int nb\_dof=0, int dof\_type=NODE\_FIELD)  
*Define mesh class to size vector.*
- size\_t **size** () const  
*Return vector (global) size.*
- PetscInt **getLocalSize** () const

- Return vector local size.*
- void **setSize** (size\_t nx, size\_t ny=1, size\_t nz=1)  
*Set vector size (for 1-D, 2-D or 3-D cases)*
- void **setDOFType** (int dof\_type)  
*Set DOF type of vector.*
- size\_t **getNbDOF** () const  
*Return vector number of degrees of freedom.*
- size\_t **getNb** () const  
*Return vector number of entities (nodes, elements or sides)*
- **Mesh** & **getMesh** () const  
*Return Mesh instance.*
- bool **isWithMesh** () const  
*Return true if vector contains a Mesh pointer, false if not.*
- int **getDOFType** () const
- void **setTime** (real\_t t)  
*Set time value for vector.*
- real\_t **getTime** () const  
*Get time value for vector.*
- void **setName** (string name)  
*Set name of vector.*
- string **getName** () const  
*Get name of vector.*
- PetscScalar **getNorm1** () const  
*Calculate 1-norm of vector.*
- PetscScalar **getNorm2** () const  
*Calculate 2-norm (Euclidean norm) of vector.*
- PetscScalar **getWNorm1** () const  
*Calculate weighted 1-norm of vector The wighted 1-norm is the 1-Norm of the vector divided by its size.*
- PetscScalar **getWNorm2** () const  
*Calculate weighted 2-norm of vector.*
- PetscScalar **getNormMax** () const  
*Calculate Max-norm (Infinite norm) of vector.*
- T\_ **getMin** () const  
*Calculate Min value of vector entries.*
- T\_ **getMax** () const  
*Calculate Max value of vector entries.*
- size\_t **getNx** () const  
*Return number of grid points in the x-direction if grid indexing is set.*
- size\_t **getNy** () const  
*Return number of grid points in the y-direction if grid indexing is set.*
- size\_t **getNz** () const  
*Return number of grid points in the z-direction if grid indexing is set.*
- void **setNodeBC** (**Mesh** &m, int code, T\_ val, size\_t dof=1)  
*Assign a given value to components of vector with given code.*
- void **setNodeBC** (**Mesh** &m, int code, const string &exp, size\_t dof=1)  
*Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.*



- void `setNodeBC` (int code, T\_ val, size\_t dof=1)  
*Assign a given value to components of vector with given code.*
- void `setNodeBC` (int code, const string &exp, size\_t dof=1)  
*Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.*
- void `removeBC` (const `Mesh` &ms, const `PETScVect`< T\_ > &v, int dof=0)  
*Remove boundary conditions.*
- void `removeBC` (const `Mesh` &ms, const `Vect`< T\_ > &v, int dof=0)  
*Remove boundary conditions.*
- void `removeBC` (const `PETScVect`< T\_ > &v, int dof=0)  
*Remove boundary conditions.*
- void `removeBC` (const `Vect`< T\_ > &v, int dof=0)  
*Remove boundary conditions.*
- void `transferBC` (const `PETScVect`< T\_ > &bc, int dof=0)  
*Transfer boundary conditions to the vector.*
- void `insertBC` (`Mesh` &m, const `PETScVect`< T\_ > &v, const `PETScVect`< T\_ > &bc, int dof=0)  
*Insert boundary conditions.*
- void `insertBC` (`Mesh` &m, const `PETScVect`< T\_ > &v, int dof=0)  
*Insert boundary conditions.*
- void `insertBC` (const `PETScVect`< T\_ > &v, const `PETScVect`< T\_ > &bc, int dof=0)  
*Insert boundary conditions.*
- void `insertBC` (const `PETScVect`< T\_ > &v, int dof=0)  
*Insert boundary conditions.*
- void `Assembly` (const `Element` &el, const T\_ \*b)  
*Assembly of element vector (as C-array) into `Vect` instance.*
- void `Assembly` (const `Side` &sd, T\_ \*b)  
*Assembly of side vector (as C-array) into `PETScVect` instance.*
- void `getGradient` (`PETScVect`< T\_ > &v)  
*Evaluate the discrete Gradient vector of the current vector.*
- void `getGradient` (`PETScVect`< `Point`< T\_ > > &v)  
*Evaluate the discrete Gradient vector of the current vector.*
- void `getCurl` (`PETScVect`< T\_ > &v)  
*Evaluate the discrete curl vector of the current vector.*
- void `getCurl` (`PETScVect`< `Point`< T\_ > > &v)  
*Evaluate the discrete curl vector of the current vector.*
- void `getSCurl` (`PETScVect`< T\_ > &v)  
*Evaluate the discrete scalar curl in 2-D of the current vector.*
- void `getDivergence` (`PETScVect`< T\_ > &v)  
*Evaluate the discrete Divergence of the current vector.*
- `real_t` `getAverage` (const `Element` &el, int type) const  
*Return average value of vector in a given element.*
- void `save` (string file, int opt)  
*Save vector in a file according to a given format.*
- `PETScVect`< T\_ > & `MultAdd` (const `PETScVect`< T\_ > &x, const T\_ &a)  
*Multiply by a constant then add to a vector.*
- void `Axpy` (T\_ a, const `PETScVect`< T\_ > &x)

- Add to vector the product of a vector by a scalar.*
- void [set](#) (size\_t i, T\_ a)  
*Assign a value to an entry for a 1-D vector.*
- void [set](#) (size\_t i, size\_t j, T\_ a)  
*Assign a value to an entry for a 2-D vector.*
- void [set](#) (size\_t i, size\_t j, size\_t k, T\_ a)  
*Assign a value to an entry for a 3-D vector.*
- void [add](#) (size\_t i, T\_ a)  
*Add a value to an entry for a 1-index vector.*
- void [add](#) (size\_t i, size\_t j, T\_ a)  
*Add a value to an entry for a 2-index vector.*
- void [add](#) (size\_t i, size\_t j, size\_t k, T\_ a)  
*Assign a value to an entry for a 3-index vector.*
- void [clear](#) ()  
*Set all vector entries to zero.*
- T\_ [operator\[\]](#) (size\_t i) const  
*Operator []*
- T\_ [operator\(\)](#) (size\_t i) const  
*Operator ()*
- T\_ [operator\(\)](#) (size\_t i, size\_t j) const  
*Operator () with 2-D indexing (Case of a grid vector)*
- T\_ [operator\(\)](#) (size\_t i, size\_t j, size\_t k) const  
*Operator () with 3-D indexing (Case of a grid vector)*
- PETScVect< T\_ > & [operator=](#) (const PETScVect< T\_ > &v)  
*Operator = between vectors.*
- PETScVect< T\_ > & [operator=](#) (const T\_ &a)  
*Operator =*
- PETScVect< T\_ > & [operator+=](#) (const PETScVect< T\_ > &v)  
*Operator +=*
- PETScVect< T\_ > & [operator+=](#) (const T\_ &a)  
*Operator +=*
- PETScVect< T\_ > & [operator-=](#) (const PETScVect< T\_ > &v)  
*Operator -=*
- PETScVect< T\_ > & [operator-=](#) (const T\_ &a)  
*Operator -=*
- PETScVect< T\_ > & [operator\\*=](#) (const T\_ &a)  
*Operator \*=*
- PETScVect< T\_ > & [operator/=](#) (const T\_ &a)  
*Operator /=*
- const [Mesh](#) & [getMeshPtr](#) () const  
*Return reference to [Mesh](#) instance.*
- T\_ [operator,](#) (const PETScVect< T\_ > &v) const  
*Return Dot (scalar) product of two vectors.*
- [operator Vec](#) () const  
*Casting operator.*
- void [setAssembly](#) ()

*Vector assembly.*

- void [Insert](#) (const vector< int > &ii, const vector< [Point](#)< T\_ > > &v)

*Insert values into certain locations of the vector.*

- void [Add](#) (const vector< int > &ii, const vector< T\_ > &v)

*Add values into certain locations of the vector.*

### 7.79.1 Detailed Description

**template<class T\_>class OFELI::PETScVect< T\_ >**

To handle general purpose vectors using Petsc.

This template class enables considering vectors of various data types. Operators =, [] and () are overloaded so that one can write for instance:

```
PETScVect<double> u(10), v(10);
v = -1.0;
u = v;
u.set(3,-2.0);
```

to set vector **v** entries to **-1**, copy vector **v** into vector **u** and assign third entry of **v** to **-2**. Note that entries of **v** are here **v(1)**, **v(2)**, ..., **v(10)**, *i.e.* vector entries start at index **1**.

Remarks

A [PETScVect](#) instance can be 1-D, 2-D or 3-D, *i.e.* one can have 1, 2 or 3 indices. This is set while the vector is constructed. This can be helpful for instance in the case of a structured grid.

Warning

This class is available only when [OFELI](#) has been installed with Petsc In this case, only vectors used for building and solving linear systems need to be instances of [PETScVect](#).

Template Parameters

|           |                                               |
|-----------|-----------------------------------------------|
| <i>T_</i> | Data type (double, int, complex<double>, ...) |
|-----------|-----------------------------------------------|

### 7.79.2 Constructor & Destructor Documentation

**PETScVect ( size.t *n* )**

Constructor setting vector size.

Parameters

|           |          |                |
|-----------|----------|----------------|
| <i>in</i> | <i>n</i> | Size of vector |
|-----------|----------|----------------|

**PETScVect ( size.t *nx*, size.t *ny* )**

Constructor of a 2-D index vector.

This constructor can be used for instance for a 2-D grid vector

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <i>in</i> | <i>nx</i> | Size for the first index  |
| <i>in</i> | <i>ny</i> | Size for the second index |

Remarks

The size of resulting vector is *nx\*ny*

**PETScVect ( size\_t *nx*, size\_t *ny*, size\_t *nz* )**

Constructor of a 3-D index vector.

This constructor can be used for instance for a 3-D grid vector

Parameters

|    |           |                           |
|----|-----------|---------------------------|
| in | <i>nx</i> | Size for the first index  |
| in | <i>ny</i> | Size for the second index |
| in | <i>nz</i> | Size for the third index  |

Remarks

The size of resulting vector is  $nx*ny*nz$

**PETScVect ( size\_t *n*, T\_\* *x* )**

Create an instance of class [PETScVect](#) as an image of a C/C++ array.

Parameters

|    |          |                                  |
|----|----------|----------------------------------|
| in | <i>n</i> | Dimension of vector to construct |
| in | <i>x</i> | C-array to copy                  |

**PETScVect ( MPI\_Comm *comm*, size\_t *n* )**

Constructor of a MPI vector using its global size.

Parameters

|    |             |                                                                       |
|----|-------------|-----------------------------------------------------------------------|
| in | <i>comm</i> | Communicator which represents all the processs that PETSc knows about |
| in | <i>n</i>    | Global size of vector                                                 |

**PETScVect ( Mesh & *m*, int *nb\_dof* = 0, int *dof\_type* = *NODE\_FIELD* )**

Constructor with a mesh instance.

Parameters

|    |                 |                                                                                                                                                                                      |
|----|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                                                        |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If <i>nb_dof</i> is set to 0 (default value) the constructor picks this number from the <a href="#">Mesh</a> instance         |
| in | <i>dof_type</i> | Type of degrees of freedom. To be given among the enumerated values: <i>NODE_FIELD</i> , <i>ELEMENT_FIELD</i> , <i>SIDE_FIELD</i> or <i>EDGE_FIELD</i> [Default: <i>NODE_FIELD</i> ] |

**PETScVect ( Mesh & *m*, string *name*, real\_t *t* = 0.0, int *nb\_dof* = 0, int *dof\_type* = *NODE\_FIELD* )**

Constructor with a mesh instance giving name and time for vector.

Parameters

|    |                 |                                                                                                                                                       |
|----|-----------------|-------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                         |
| in | <i>name</i>     | Name of the vector                                                                                                                                    |
| in | <i>t</i>        | Time value for the vector                                                                                                                             |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If nb_dof is set to 0 the constructor picks this number from the <a href="#">Mesh</a> instance |
| in | <i>dof_type</i> | Type of degrees of freedom. To be given among the enumerated values: NODE_FIELD, ELEMENT_FIELD, SIDE_FIELD or EDGE_FIELD [Default: NODE_FIELD]        |

**PETScVect ( const PETScVect< T\_ > & v, const PETScVect< T\_ > & bc )**

Constructor using boundary conditions.

Boundary condition values contained in bc are reported to vector v

Parameters

|    |           |                                                                             |
|----|-----------|-----------------------------------------------------------------------------|
| in | <i>v</i>  | <a href="#">PETScVect</a> instance to update                                |
| in | <i>bc</i> | <a href="#">PETScVect</a> instance containing imposed valued at desired DOF |

**PETScVect ( const PETScVect< T\_ > & v, size\_t nb\_dof, size\_t first\_dof )**

Constructor to select some components of a given vector.

Parameters

|    |                  |                                                                                                                                     |
|----|------------------|-------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>         | <a href="#">PETScVect</a> instance to extract from                                                                                  |
| in | <i>nb_dof</i>    | Number of DOF to extract                                                                                                            |
| in | <i>first_dof</i> | First DOF to extract For instance, a choice first_dof=2 and nb_dof=1 means that the second DOF of each node is copied in the vector |

**PETScVect ( const PETScVect< T\_ > & v, size\_t n )**

Constructor to select one component from a given 2 or 3-component vector.

Parameters

|    |          |                                                    |
|----|----------|----------------------------------------------------|
| in | <i>v</i> | <a href="#">PETScVect</a> instance to extract from |
| in | <i>n</i> | Component to extract (must be > 1 and < 4 or).     |

**PETScVect ( size\_t d, const PETScVect< T\_ > & v, const string & name = " " )**

Constructor that extracts some degrees of freedom (components) from given instance of [PETScVect](#).

This constructor enables constructing a subvector of a given [PETScVect](#) instance. It selects a given list of degrees of freedom and put it according to a given order in the instance to construct.

Parameters

|    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
|----|-------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>d</i>    | Integer number giving the list of degrees of freedom. This number is made of <i>n</i> digits where <i>n</i> is the number of degrees of freedom. Let us give an example: Assume that the instance <i>v</i> has 3 DOF by entity (node, element or side). The choice <i>d</i> =201 means that the constructed instance has 2 DOF where the first DOF is the third one of <i>v</i> , and the second DOF is the first one of <i>f v</i> . Consequently, no digit can be larger than the number of DOF the constructed instance. In this example, a choice <i>d</i> =103 would produce an error message. |
| in | <i>v</i>    | <a href="#">PETScVect</a> instance from which extraction is performed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |
| in | <i>name</i> | Name to assign to vector instance [Default: ""].                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |

### Warning

Don't give zeros as first digits for the argument *d*. The number is in this case interpreted as octal !!

## 7.79.3 Member Function Documentation

**void set ( const T\_ \* *v*, size\_t *n* )**

Initialize vector with a c-array.

Parameters

|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>v</i> | c-array (pointer) to initialize <a href="#">PETScVect</a> |
| in | <i>n</i> | size of array                                             |

**void setMPI ( MPI.Comm *comm*, size\_t *n*, size\_t *N* )**

Initialize a local vector using MPI.

Parameters

|    |             |                       |
|----|-------------|-----------------------|
| in | <i>comm</i> |                       |
| in | <i>n</i>    | local size of vector  |
| in | <i>N</i>    | global size of vector |

**void select ( const PETScVect< T\_ > & *v*, size\_t *nb\_dof* = 0, size\_t *first\_dof* = 1 )**

Initialize vector with another [PETScVect](#) instance.

Parameters

|    |                  |                                                                                                                                                                  |
|----|------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>         | <a href="#">PETScVect</a> instance to extract from                                                                                                               |
| in | <i>nb_dof</i>    | Number of DOF per node, element or side (By default, 0: Number of degrees of freedom extracted from the <a href="#">Mesh</a> instance)                           |
| in | <i>first_dof</i> | First DOF to extract (Default: 1) For instance, a choice <i>first_dof</i> =2 and <i>nb_dof</i> =1 means that the second DOF of each node is copied in the vector |

**void set ( const string & *exp*, size\_t *dof* = 1 )**

Initialize vector with an algebraic expression.

Parameters

|    |            |                                                                                                    |
|----|------------|----------------------------------------------------------------------------------------------------|
| in | <i>exp</i> | Regular algebraic expression that defines a function of x, y and z which are coordinates of nodes. |
| in | <i>dof</i> | Degree of freedom to which the value is assigned [Default: 1]                                      |

**void set ( const Mesh & ms, const string & exp, size\_t dof = 1 )**

Initialize vector with an algebraic expression with providing mesh data.

Parameters

|    |            |                                                                                                    |
|----|------------|----------------------------------------------------------------------------------------------------|
| in | <i>ms</i>  | <a href="#">Mesh</a> instance                                                                      |
| in | <i>exp</i> | Regular algebraic expression that defines a function of x, y and z which are coordinates of nodes. |
| in | <i>dof</i> | Degree of freedom to which the value is assigned [Default: 1]                                      |

**void set ( const PETScVect< real\_t > & x, const string & exp )**

Initialize vector with an algebraic expression.

Parameters

|    |            |                                                                                                                             |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------|
| in | <i>x</i>   | <a href="#">PETScVect</a> instance that contains coordinates of points                                                      |
| in | <i>exp</i> | Regular algebraic expression that defines a function of x and i which are coordinates of nodes and indices starting from 1. |

**void setMesh ( Mesh & m, int nb\_dof = 0, int dof\_type = NODE\_FIELD )**

Define mesh class to size vector.

Parameters

|    |                 |                                                                                                                                                                        |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                                          |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If nb_dof is set to 0 the constructor picks this number from the <a href="#">Mesh</a> instance                  |
| in | <i>dof_type</i> | Parameter to precise the type of degrees of freedom. To be chosen among the enumerated values: NODE_FIELD, ELEMENT_FIELD, SIDE_FIELD, EDGE_FIELD [Default: NODE_FIELD] |

**PetscInt getLocalSize ( ) const**

Return vector local size.

Local size is the size on the current processor

**void setSize ( size\_t nx, size\_t ny = 1, size\_t nz = 1 )**

Set vector size (for 1-D, 2-D or 3-D cases)

This function allocates memory for the vector but does not initialize its components

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>nx</i> | Number of grid points in x-direction              |
| in | <i>ny</i> | Number of grid points in y-direction [Default: 1] |
| in | <i>nz</i> | Number of grid points in z-direction [Default: 1] |

**void setDOFType ( int dof\_type )**

Set DOF type of vector.

The DOF type combined with number of DOF per component enable determining the size of vector

Parameters

|    |                 |                                                                                                                                                                                       |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | Type of degrees of freedom. Value to be chosen among the enumerated values: <code>NODE_FIELD</code> , <code>ELEMENT_FIELD</code> , <code>SIDE_FIELD</code> or <code>EDGE_FIELD</code> |
|----|-----------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**bool isWithMesh ( ) const**

Return true if vector contains a [Mesh](#) pointer, false if not.

A [PETScVect](#) instance can be constructed using mesh information

**int getDOFType ( ) const**

Return DOF type of vector

Returns

*dof\_type* Type of degrees of freedom. Value among the enumerated values: `NODE_FIELD`, `ELEMENT_FIELD`, `SIDE_FIELD` or `EDGE_FIELD`

**PetscScalar getWNorm2 ( ) const**

Calculate weighted 2-norm of vector.

The weighted 2-norm is the 2-Norm of the vector divided by the square root of its size

**void setNodeBC ( Mesh & m, int code, T\_ val, size\_t dof = 1 )**

Assign a given value to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>m</i>    | Instance of mesh                                               |
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>val</i>  | Value to prescribe                                             |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |

**void setNodeBC ( Mesh & m, int code, const string & exp, size\_t dof = 1 )**

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>m</i>    | Instance of mesh                                               |
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>exp</i>  | Regular algebraic expression to prescribe                      |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |



**void setNodeBC ( int *code*, T\_ *val*, size\_t *dof* = 1 )**

Assign a given value to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>val</i>  | Value to prescribe                                             |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [Default: 1] |

**void setNodeBC ( int *code*, const string & *exp*, size\_t *dof* = 1 )**

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>exp</i>  | Regular algebraic expression to prescribe                      |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [Default: 1] |

**void removeBC ( const Mesh & *ms*, const PETScVect< T\_ > & *v*, int *dof* = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                             |
|----|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ms</i>  | <a href="#">Mesh</a> instance                                                                                                                                                               |
| in | <i>v</i>   | Vector ( <a href="#">PETScVect</a> instance to copy from)                                                                                                                                   |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom |

**void removeBC ( const Mesh & *ms*, const Vect< T\_ > & *v*, int *dof* = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                             |
|----|------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ms</i>  | <a href="#">Mesh</a> instance                                                                                                                                                               |
| in | <i>v</i>   | Vector ( <a href="#">Vect</a> instance to copy from)                                                                                                                                        |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom |

**void removeBC ( const PETScVect< T\_ > & *v*, int *dof* = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | Vector ( <a href="#">PETScVect</a> instance to copy from)                                                                                                                                    |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom. |

Remarks

This function is to be used only when the [PETScVect](#) instance was constructed by using the [Mesh](#) instance

**void removeBC ( const Vect< T\_ > & v, int dof = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | Vector ( <a href="#">Vect</a> instance to copy from)                                                                                                                                         |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom. |

Remarks

This function is to be used only when the [PETScVect](#) instance was constructed by using the [Mesh](#) instance

**void transferBC ( const PETScVect< T\_ > & bc, int dof = 0 )**

Transfer boundary conditions to the vector.

Parameters

|    |            |                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>bc</i>  | <a href="#">PETScVect</a> instance from which imposed degrees of freedom are copied to current instance                                                                                      |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom. |

**void insertBC ( Mesh & m, const PETScVect< T\_ > & v, const PETScVect< T\_ > & bc, int dof = 0 )**

Insert boundary conditions.

Parameters

|    |            |                                                                                                                                                                                                             |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>   | <a href="#">Mesh</a> instance.                                                                                                                                                                              |
| in | <i>v</i>   | <a href="#">PETScVect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                       |
| in | <i>bc</i>  | <a href="#">PETScVect</a> instance from which imposed degrees of freedom are copied to current instance.                                                                                                    |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( Mesh & *m*, const PETScVect< T\_ > & *v*, int *dof* = 0 )**

Insert boundary conditions.

DOF with imposed boundary conditions are set to zero.

Parameters

|    |            |                                                                                                                                                                                                             |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>   | <a href="#">Mesh</a> instance.                                                                                                                                                                              |
| in | <i>v</i>   | <a href="#">PETScVect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                       |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( const PETScVect< T\_ > & *v*, const PETScVect< T\_ > & *bc*, int *dof* = 0 )**

Insert boundary conditions.

Parameters

|    |            |                                                                                                                                                                                                             |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | <a href="#">PETScVect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                       |
| in | <i>bc</i>  | <a href="#">PETScVect</a> instance from which imposed degrees of freedom are copied to current instance.                                                                                                    |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( const PETScVect< T\_ > & *v*, int *dof* = 0 )**

Insert boundary conditions.

DOF with imposed boundary conditions are set to zero.

Parameters

|    |            |                                                                                                                                                                                                             |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | <a href="#">PETScVect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                       |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void Assembly ( const Element & *el*, const T\_ \* *b* )**

Assembly of element vector (as C-array) into [Vect](#) instance.

Parameters

|    |           |                                    |
|----|-----------|------------------------------------|
| in | <i>el</i> | Reference to element instance      |
| in | <i>b</i>  | Local vector to assemble (C-Array) |

**void Assembly ( const Side & *sd*, T\_ \* *b* )**

Assembly of side vector (as C-array) into [PETScVect](#) instance.

Parameters

|    |           |                                    |
|----|-----------|------------------------------------|
| in | <i>sd</i> | Reference to side instance         |
| in | <i>b</i>  | Local vector to assemble (C-Array) |

**void getGradient ( PETScVect< T\_ > & v )**

Evaluate the discrete Gradient vector of the current vector.

The resulting gradient is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The gradient is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                               |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the gradient, where $v(n,1)$ , $v(n,2)$ and $v(n,3)$ are respectively the x and y and z derivatives at element n. |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getGradient ( PETScVect< Point< T\_ > > & v )**

Evaluate the discrete Gradient vector of the current vector.

The resulting gradient is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The gradient is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the gradient, where $v(n,1) .x$ , $v(n,2) .y$ and $v(n,3) .z$ are respectively the x and y and z derivatives at element n. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getCurl ( PETScVect< T\_ > & v )**

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The curl is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                               |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the curl, where $v(n,1)$ , $v(n,2)$ and $v(n,3)$ are respectively the x and y and z curl components at element n. |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getCurl ( PETScVect< Point< T\_ > > & v )**

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The curl is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the curl, where $v(n,1) .x$ , $v(n,2) .y$ and $v(n,3) .z$ are respectively the x and y and z curl components at element n. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getSCurl ( PETScVect< T\_ > & v )**

Evaluate the discrete scalar curl in 2-D of the current vector.

The resulting curl is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The curl is then a constant vector for each element.

Parameters

|    |          |                                                              |
|----|----------|--------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the scalar curl. |
|----|----------|--------------------------------------------------------------|

**void getDivergence ( PETScVect< T\_ > & v )**

Evaluate the discrete Divergence of the current vector.

The resulting divergence is stored in a [PETScVect](#) instance This function handles node vectors assuming  $P_1$  approximation The divergence is then a constant vector for each element.

Parameters

|    |          |                                                             |
|----|----------|-------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the divergence. |
|----|----------|-------------------------------------------------------------|

**real\_t getAverage ( const Element & el, int type ) const**

Return average value of vector in a given element.

Parameters

|    |             |                                                                                                     |
|----|-------------|-----------------------------------------------------------------------------------------------------|
| in | <i>el</i>   | <a href="#">Element</a> instance                                                                    |
| in | <i>type</i> | Type of element. This is to be chosen among enumerated values: LINE2, TRIANG3, QUAD4, TETRA4, HEXA8 |

**void save ( string file, int opt )**

Save vector in a file according to a given format.

Parameters

|    |             |                                                                                                                            |
|----|-------------|----------------------------------------------------------------------------------------------------------------------------|
| in | <i>file</i> | Output file where to save the vector                                                                                       |
| in | <i>opt</i>  | Option to choose file format to save. This is to be chosen among enumerated values: GMSH, GNUPLOT, MATLAB, TECPLOT and VTK |

**PETScVect<T\_>& MultAdd ( const PETScVect< T\_ > & x, const T\_ & a )**

Multiply by a constant then add to a vector.

Parameters

|    |          |                                           |
|----|----------|-------------------------------------------|
| in | <i>x</i> | <a href="#">PETScVect</a> instance to add |
| in | <i>a</i> | Constant to multiply before adding        |

**void Axy ( T\_ a, const PETScVect< T\_ > & x )**

Add to vector the product of a vector by a scalar.

Parameters

|    |          |                                                                                                 |
|----|----------|-------------------------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                                           |
| in | <i>x</i> | <a href="#">Vect</a> instance by which a is multiplied. The result is added to current instance |

**void set ( size\_t i, T\_ a )**

Assign a value to an entry for a 1-D vector.

Parameters

|                 |                |                                    |
|-----------------|----------------|------------------------------------|
| <code>in</code> | <code>i</code> | Rank index in vector (starts at 1) |
| <code>in</code> | <code>a</code> | Value to assign                    |

**void set ( size\_t *i*, size\_t *j*, T\_ *a* )**

Assign a value to an entry for a 2-D vector.

Parameters

|                 |                |                                      |
|-----------------|----------------|--------------------------------------|
| <code>in</code> | <code>i</code> | First index in vector (starts at 1)  |
| <code>in</code> | <code>j</code> | Second index in vector (starts at 1) |
| <code>in</code> | <code>a</code> | Value to assign                      |

**void set ( size\_t *i*, size\_t *j*, size\_t *k*, T\_ *a* )**

Assign a value to an entry for a 3-D vector.

Parameters

|                 |                |                                      |
|-----------------|----------------|--------------------------------------|
| <code>in</code> | <code>i</code> | First index in vector (starts at 1)  |
| <code>in</code> | <code>j</code> | Second index in vector (starts at 1) |
| <code>in</code> | <code>k</code> | Third index in vector (starts at 1)  |
| <code>in</code> | <code>a</code> | Value to assign                      |

**void add ( size\_t *i*, T\_ *a* )**

Add a value to an entry for a 1-index vector.

Parameters

|                 |                |                                    |
|-----------------|----------------|------------------------------------|
| <code>in</code> | <code>i</code> | Rank index in vector (starts at 1) |
| <code>in</code> | <code>a</code> | Value to assign                    |

**void add ( size\_t *i*, size\_t *j*, T\_ *a* )**

Add a value to an entry for a 2-index vector.

Parameters

|                 |                |                                      |
|-----------------|----------------|--------------------------------------|
| <code>in</code> | <code>i</code> | First index in vector (starts at 1)  |
| <code>in</code> | <code>j</code> | Second index in vector (starts at 1) |
| <code>in</code> | <code>a</code> | Value to assign                      |

**void add ( size\_t *i*, size\_t *j*, size\_t *k*, T\_ *a* )**

Assign a value to an entry for a 3-index vector.

Parameters

|                 |                |                                      |
|-----------------|----------------|--------------------------------------|
| <code>in</code> | <code>i</code> | First index in vector (starts at 1)  |
| <code>in</code> | <code>j</code> | Second index in vector (starts at 1) |
| <code>in</code> | <code>k</code> | Third index in vector (starts at 1)  |
| <code>in</code> | <code>a</code> | Value to assign                      |

**T\_ operator[] ( size\_t i ) const**

Operator []



Parameters

|                 |                |                                    |
|-----------------|----------------|------------------------------------|
| <code>in</code> | <code>i</code> | Rank index in vector (starts at 0) |
|-----------------|----------------|------------------------------------|

**T\_ operator() ( size\_t i ) const**

Operator ()

Parameters

|                 |                |                                                                                                                                                                                                                                        |
|-----------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | Rank index in vector (starts at 1) <ul style="list-style-type: none"> <li>• <code>v(i)</code> starts at <code>v(1)</code> to <code>v(size())</code></li> <li>• <code>v(i)</code> is the same element as <code>v[i-1]</code></li> </ul> |
|-----------------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**T\_ operator() ( size\_t i, size\_t j ) const**

Operator () with 2-D indexing (Case of a grid vector)

Parameters

|                 |                |                                                                                                                                                           |
|-----------------|----------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | first index in vector (Number of vector components in the x-grid)                                                                                         |
| <code>in</code> | <code>j</code> | second index in vector (Number of vector components in the y-grid) <code>v(i, j)</code> starts at <code>v(1,1)</code> to <code>v(getNx(), getNy())</code> |

**T\_ operator() ( size\_t i, size\_t j, size\_t k ) const**

Operator () with 3-D indexing (Case of a grid vector)

Parameters

|                 |                |                                                                                                                                                                        |
|-----------------|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | first index in vector (Number of vector components in the x-grid)                                                                                                      |
| <code>in</code> | <code>j</code> | second index in vector (Number of vector components in the y-grid)                                                                                                     |
| <code>in</code> | <code>k</code> | third index in vector (Number of vector components in the z-grid) <code>v(i, j, k)</code> starts at <code>v(1,1,1)</code> to <code>v(getNx(), getNy(), getNz())</code> |

**PETScVect<T\_>& operator= ( const T\_ & a )**

Operator =

Assign a constant to vector entries

Parameters

|                 |                |              |
|-----------------|----------------|--------------|
| <code>in</code> | <code>a</code> | Value to set |
|-----------------|----------------|--------------|

**PETScVect<T\_>& operator+= ( const PETScVect< T\_ > & v )**

Operator +=

Add vector x to current vector instance.

Parameters

|    |          |                                                       |
|----|----------|-------------------------------------------------------|
| in | <i>v</i> | <a href="#">PETScVect</a> instance to add to instance |
|----|----------|-------------------------------------------------------|

**PETScVect<T\_>& operator+= ( const T\_ & *a* )**

Operator +=

Add a constant to current vector entries.

Parameters

|    |          |                                |
|----|----------|--------------------------------|
| in | <i>a</i> | Value to add to vector entries |
|----|----------|--------------------------------|

**PETScVect<T\_>& operator-= ( const PETScVect< T\_ > & *v* )**

Operator -=

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance to subtract from |
|----|----------|------------------------------------------------|

**PETScVect<T\_>& operator-= ( const T\_ & *a* )**

Operator -=

Subtract constant from vector entries.

Parameters

|    |          |                        |
|----|----------|------------------------|
| in | <i>a</i> | Value to subtract from |
|----|----------|------------------------|

**PETScVect<T\_>& operator\*= ( const T\_ & *a* )**

Operator \*=

Parameters

|    |          |                      |
|----|----------|----------------------|
| in | <i>a</i> | Value to multiply by |
|----|----------|----------------------|

**PETScVect<T\_>& operator/= ( const T\_ & *a* )**

Operator /=

Parameters

|    |          |                    |
|----|----------|--------------------|
| in | <i>a</i> | Value to divide by |
|----|----------|--------------------|

**T\_ operator, ( const PETScVect< T\_ > & *v* ) const**

Return Dot (scalar) product of two vectors.

A typical use of this operator is `double a = (v,w)` where *v* and *w* are 2 instances of `PETScVect<double>`

Parameters

|    |          |                                                                                |
|----|----------|--------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">PETScVect</a> instance by which the current instance is multiplied |
|----|----------|--------------------------------------------------------------------------------|

**operator Vec ( ) const**

Casting operator.

This member functions enables casting an instance of class [PETScVect](#) into the `Petsc` vector type `Vec`. This is useful when one wants to use any `Petsc` function that is not available in the wrapper (class [PETScWrapper](#)) or [PETScVect](#).

**void setAssembly ( )**

Vector assembly.

This function assembles vector (begins and ends)

**void Insert ( const vector< int > & ii, const vector< Point< T\_ > > & v )**

Insert values into certain locations of the vector.

Parameters

|                 |                 |                                                                                                                                              |
|-----------------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>ii</code> | Vector containing indices where to insert (Note the indices start from 0 like any C-array)                                                   |
| <code>in</code> | <code>v</code>  | Vector of values to insert, corresponding to indices in <code>ii</code> . Here the vector has entries of type <code>Point&lt;T_&gt;</code> . |

**void Add ( const vector< int > & ii, const vector< T\_ > & v )**

Add values into certain locations of the vector.

Parameters

|                 |                 |                                                                                         |
|-----------------|-----------------|-----------------------------------------------------------------------------------------|
| <code>in</code> | <code>ii</code> | Vector containing indices where to add (Note the indices start from 0 like any C-array) |
| <code>in</code> | <code>v</code>  | Vector of values to add, corresponding to indices in <code>ii</code>                    |

## 7.80 PETScWrapper< T\_ > Class Template Reference

This class is a wrapper to be used when the library `Petsc` is installed and used with [OFELI](#).

### Public Member Functions

- [PETScWrapper](#) (int argc, char \*\*args, string help="")  
*Constructor with program arguments.*
- [~PETScWrapper](#) ()  
*Destructor.*
- `PetscErrorCode` [getIntOption](#) (string s, `PetscInt` &n, `PetscBool` &set) const  
*Get an option as an integer number.*
- `PetscErrorCode` [getBoolOption](#) (string s, `PetscBool` &b, `PetscBool` &set) const  
*Get an option as a bool variable.*
- `PetscMPIInt` [size](#) () const  
*Return wrapper size, i.e. number of processors.*
- void [setMesh](#) ([Mesh](#) &ms)  
*Set mesh.*
- void [setPartition](#) ([Partition](#) &p)  
*Set mesh partition.*

- void [setMatrix](#) (PETScMatrix< T\_ > &A)  
*Define problem matrix.*
- void [setLinearSystem](#) (PETScMatrix< T\_ > &A, PETScVect< T\_ > &b, string s=KSPCG, string p=PCJACOBI, [real.t](#) tol=1.e-12, [size.t](#) max\_it=1000)  
*Set linear system features.*
- void [setPreconditioner](#) (string p)  
*Choose preconditioner for the iterative procedure.*
- void [setIterationParameters](#) ([real.t](#) tol, [size.t](#) max\_it)  
*Choose iteration parameters.*
- void [setIterationMethod](#) (string m)  
*Choose the iterative method.*
- void [solve](#) (PETScVect< T\_ > &x)  
*Solve the linear system.*
- void [solve](#) (const PETScVect< T\_ > &b, PETScVect< T\_ > &x)  
*Solve the linear system.*
- void [checkError](#) (PETScVect< T\_ > &u) const  
*Check residual error.*
- int [getIterationNumber](#) () const  
*Return the number of iterations.*
- void [setLSTolerances](#) ([real.t](#) rel\_tol, [real.t](#) abs\_tol, [real.t](#) div\_tol=PETSC.DEFAULT, int max\_it=PETSC.DEFAULT) const  
*Set tolerance parameters for a linear system.*
- PetscMPIInt [getRank](#) () const  
*Return the rank of the current processor.*

## Friends

- template<class S\_ >  
ostream & [operator<<](#) (ostream &s, const [PETScWrapper](#)< S\_ > &w)  
*Output wrapper information.*

### 7.80.1 Detailed Description

**template<class T\_>class OFELI::PETScWrapper< T\_ >**

This class is a wrapper to be used when the library Petsc is installed and used with [OFELI](#).

When Petsc is used, an instance of class [PETScWrapper](#) is to be declared. It initializes the use of Petsc and enables calling solver functions in Petsc.

Template Parameters

|      |                                               |
|------|-----------------------------------------------|
| $T_$ | Data type (double, int, complex<double>, ...) |
|------|-----------------------------------------------|

When a linear system is invoked, the choice of iterative solvers can be made among the following methods (see Petsc documentation for more details):

- KSPRICHARDSON: The Richardson iterative method (Default damping parameter is 1.0)
- KSPCHEBYSHEV: The Chebyshev iterative method
- KSPCG: The conjugate gradient method [Default]
- KSPCGNE: The CG method for normal equations (without explicitly forming the product  $A^T A$ )

- **KSPGMRES:** [Default] The GMRES iterative method (see A Generalized Minimal Residual Algorithm for Solving Nonsymmetric Linear Systems. Y. Saad and M. H. Schultz, SIAM J. Sci. Stat. Comput., Vol. 7, No. 3, July 1986, pp. 856-869)
- **KSPFGMRES:** The Flexible GMRES method (with restart)
- **KSP\_LGMRES:** The 'augmented' standard GMRES method where the subspace uses approximations to the error from previous restart cycles
- **KSP\_TCQMR:** A variant of QMR (quasi minimal residual) developed by Tony Chan
- **KSPBCGS:** The BiCGStab (Stabilized version of BiConjugate Gradient Squared) method
- **KSP\_IBCGS:** The IBiCGStab (Improved Stabilized version of BiConjugate Gradient Squared) method in an alternative form to have only a single global reduction operation instead of the usual 3 (or 4)
- **KSPFBCGS:** The flexible BiCGStab method.
- **KSPCGS:** The CGS (Conjugate Gradient Squared) method
- **KSP\_TFQMR:** A transpose free QMR (quasi minimal residual)
- **KSPCR:** The conjugate residuals method
- **KSP\_LSQR:** The LSQR method
- **KSP\_BICG:** The Biconjugate gradient method (similar to running the conjugate gradient on the normal equations)
- **KSP\_MINRES:** The MINRES (Minimum Residual) method
- **KSP\_SYMLQ:** The SYMLQ method
- **KSP\_GCR:** The Generalized Conjugate Residual method

When a linear system is invoked, the choice of a preconditioner can be made among the following methods (see Petsc documentation for more details):

- **PCJACOBI:** [Default] Jacobi (*i.e.* diagonal scaling) preconditioning
- **PCBJACOBI:** Block Jacobi preconditioning, each block is (approximately) solved with its own KSP object
- **PCSOR:** (S)SOR (successive over relaxation, Gauss-Seidel) preconditioning
- **PCEISENSTAT:** An implementation of SSOR (symmetric successive over relaxation, symmetric Gauss-Seidel) preconditioning that incorporates Eisenstat's trick to reduce the amount of computation needed
- **PCICC:** Incomplete Cholesky factorization preconditioners
- **PCILU:** Incomplete factorization preconditioners
- **PCASM:** Use the (restricted) additive Schwarz method, each block is (approximately) solved with its own KSP object
- **PCLU:** Uses a direct solver, based on LU factorization, as a preconditioner
- **PCCHOLESKY:** Uses a direct solver, based on Cholesky factorization, as a preconditioner

## 7.80.2 Constructor & Destructor Documentation

**PETScWrapper** ( *int argc*, *char \*\* args*, *string help* = "" )

Constructor with program arguments.

## Parameters

|    |      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----|------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | argc | Count of number of command line arguments                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| in | args | <p>The command line arguments. Here is the list of arguments:</p> <ul style="list-style-type: none"> <li>• <code>-start_in_debugger</code> [noxtterm,dbx,xdb,gdb,...] <ul style="list-style-type: none"> <li>– Starts program in debugger</li> </ul> </li> <li>• <code>-on_error_attach_debugger</code> [noxtterm,dbx,xdb,gdb,...] <ul style="list-style-type: none"> <li>– Starts debugger when error detected</li> </ul> </li> <li>• <code>-on_error_emacs</code> &lt;machinename&gt; causes emacsclient to jump to error file <ul style="list-style-type: none"> <li>– . <code>-on_error_abort</code> calls <code>abort()</code> when error detected (no traceback)</li> </ul> </li> <li>• <code>-on_error_mpiabort</code> calls <code>MPI.abort()</code> when error detected <ul style="list-style-type: none"> <li>– . <code>-error_output_stderr</code> prints error messages to stderr instead of the default stdout</li> </ul> </li> <li>• <code>-error_output_none</code> does not print the error messages (but handles errors in the same way as if this was not called) <ul style="list-style-type: none"> <li>– . <code>-debugger_nodes</code> [node1,node2,...] - Indicates nodes to start in debugger</li> </ul> </li> <li>• <code>-debugger_pause</code> [sleeptime] (in seconds) <ul style="list-style-type: none"> <li>– Pauses debugger</li> </ul> </li> <li>• <code>-stop_for_debugger</code> <ul style="list-style-type: none"> <li>– Print message on how to attach debugger manually to process and wait (<code>-debugger_pause</code>) seconds for attachment</li> </ul> </li> <li>• <code>-malloc</code> <ul style="list-style-type: none"> <li>– Indicates use of PETSc error-checking malloc (on by default for debug version of libraries)</li> </ul> </li> <li>• <code>-malloc no</code> <ul style="list-style-type: none"> <li>– Indicates not to use error-checking malloc</li> </ul> </li> <li>• <code>-malloc_debug</code> <ul style="list-style-type: none"> <li>– check for memory corruption at EVERY malloc or free</li> </ul> </li> <li>• <code>-malloc_dump</code> <ul style="list-style-type: none"> <li>– prints a list of all unfreed memory at the end of the run</li> </ul> </li> <li>• <code>-malloc_test</code> <ul style="list-style-type: none"> <li>– like <code>-malloc_dump</code> <code>-malloc_debug</code>, but only active for debugging builds</li> </ul> </li> <li>• <code>-fp_trap</code> <ul style="list-style-type: none"> <li>– Stops on floating point exceptions (Note that on the IBM RS6000 this slows code by at least a factor of 10.)</li> </ul> </li> <li>• <code>-no_signal_handler</code> <ul style="list-style-type: none"> <li>– Indicates not to trap error signals</li> </ul> </li> <li>• <code>-shared_tmp</code></li> </ul> |

### Warning

This class is available only when [OFELI](#) has been installed with Petsc

### ~PETScWrapper ( )

Destructor.

Destroy the KSP context and release memory allocated by Petsc

### 7.80.3 Member Function Documentation

#### PetscErrorCode getIntOption ( string *s*, PetscInt & *n*, PetscBool & *set* ) const

Get an option as an integer number.

Parameters

|     |            |                                          |
|-----|------------|------------------------------------------|
| in  | <i>s</i>   | String to prepend the name of the option |
| out | <i>n</i>   | Obtained integer value                   |
| out | <i>set</i> | true if found, false if not.             |

#### PetscErrorCode getBoolOption ( string *s*, PetscBool & *b*, PetscBool & *set* ) const

Get an option as a bool variable.

Parameters

|     |            |                                          |
|-----|------------|------------------------------------------|
| in  | <i>s</i>   | String to prepend the name of the option |
| out | <i>b</i>   | Obtained boolean value                   |
| out | <i>set</i> | true if found, false if not.             |

#### void setMesh ( Mesh & *ms* )

Set mesh.

Parameters

|    |           |                               |
|----|-----------|-------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance |
|----|-----------|-------------------------------|

#### void setPartition ( Partition & *p* )

Set mesh partition.

This function is to be used for parallel computing

Parameters

|    |          |                                    |
|----|----------|------------------------------------|
| in | <i>p</i> | <a href="#">Partition</a> instance |
|----|----------|------------------------------------|

#### void setMatrix ( PETScMatrix< T\_ > & *A* )

Define problem matrix.

Parameters

|    |          |                                                           |
|----|----------|-----------------------------------------------------------|
| in | <i>A</i> | <a href="#">PETScMatrix</a> instance that contains matrix |
|----|----------|-----------------------------------------------------------|

**void setLinearSystem ( PETScMatrix< T\_ > & A, PETScVect< T\_ > & b, string s = *KSPCG*, string p = *PCJACOBI*, real.t tol = 1.e-12, size.t max.it = 1000 )**

Set linear system features.

Parameters

|    |               |                                                                                                 |
|----|---------------|-------------------------------------------------------------------------------------------------|
| in | <i>A</i>      | <a href="#">PETScMatrix</a> instance that contains matrix                                       |
| in | <i>b</i>      | Vector containing the right-hand side                                                           |
| in | <i>s</i>      | Option to choose iterative solver. See the definition of the class for iterative methods        |
| in | <i>p</i>      | Option to choose preconditioner. See the definition of the class for available preconditioners. |
| in | <i>tol</i>    | Tolerance for convergence of iteration process [Default: 1.e-12]                                |
| in | <i>max.it</i> | Maximum number of linear solver iterations [Default: 1000]                                      |

**void setPreconditioner ( string p )**

Choose preconditioner for the iterative procedure.

Parameters

|    |          |                                                                                                 |
|----|----------|-------------------------------------------------------------------------------------------------|
| in | <i>p</i> | Option to choose preconditioner. See the definition of the class for available preconditioners. |
|----|----------|-------------------------------------------------------------------------------------------------|

**void setIterationParameters ( real.t tol, size.t max.it )**

Choose iteration parameters.

Parameters

|    |               |                                                |
|----|---------------|------------------------------------------------|
| in | <i>tol</i>    | Tolerance for convergence of iteration process |
| in | <i>max.it</i> | Maximum number of linear solver iterations     |

**void setIterationMethod ( string m )**

Choose the iterative method.

Parameters

|    |          |                                                                                                     |
|----|----------|-----------------------------------------------------------------------------------------------------|
| in | <i>m</i> | Option to choose iterative solver. See the definition of the class for available iterative solvers. |
|----|----------|-----------------------------------------------------------------------------------------------------|

**void solve ( PETScVect< T\_ > & x )**

Solve the linear system.

If the member functions setIterationMethod and setPreconditioner have not been used, default methods are used



Parameters

|        |     |                                                                                                      |
|--------|-----|------------------------------------------------------------------------------------------------------|
| in,out | $x$ | Vector containing the initial guess on input and, if convergence is achieved, the solution on output |
|--------|-----|------------------------------------------------------------------------------------------------------|

**void solve ( const PETScVect< T\_ > & b, PETScVect< T\_ > & x )**

Solve the linear system.

If the member functions setIterationMethod and setPreconditioner have not been used, default methods are used

Parameters

|        |     |                                                                                                      |
|--------|-----|------------------------------------------------------------------------------------------------------|
| in     | $b$ | Vector containing the right-hand side                                                                |
| in,out | $x$ | Vector containing the initial guess on input and, if convergence is achieved, the solution on output |

**void checkError ( PETScVect< T\_ > & u ) const**

Check residual error.

This function computes the residual  $A*x - b$  and outputs the number of iterations

Parameters

|     |     |                 |
|-----|-----|-----------------|
| out | $u$ | Residual vector |
|-----|-----|-----------------|

**void setLSTolerances ( real.t rel\_tol, real.t abs\_tol, real.t div\_tol = PETSC\_DEFAULT, int max\_it = PETSC\_DEFAULT ) const**

Set tolerance parameters for a linear system.

Parameters

|    |            |                                                                                       |
|----|------------|---------------------------------------------------------------------------------------|
| in | $rel\_tol$ | Relative convergence tolerance, relative decrease in the preconditioned residual norm |
| in | $abs\_tol$ | Absolute convergence tolerance of the preconditioned residual norm                    |
| in | $div\_tol$ | Divergence tolerance: Amount preconditioned residual norm                             |
| in | $max\_it$  | Maximum number of iterations                                                          |

## 7.81 PhaseChange Class Reference

This class enables defining phase change laws for a given material.

### Public Member Functions

- virtual [~PhaseChange](#) ()  
*Destructor.*
- int [E2T](#) (real.t &H, real.t &T, real.t &gamma)  
*Calculate temperature from enthalpy.*
- virtual int [EnthalpyToTemperature](#) (real.t &H, real.t &T, real.t &gamma)  
*Virtual function to calculate temperature from enthalpy.*
- void [setMaterial](#) (Material &m, int code)  
*Choose [Material](#) instance and material code.*

- [Material](#) & [getMaterial](#) () const

*Return reference to [Material](#) instance.*

### 7.81.1 Detailed Description

This class enables defining phase change laws for a given material.

These laws are predefined for a certain number of materials. The user can set himself a specific behavior for his own materials by defining a class that inherits from [PhaseChange](#). The derived class must have at least the member function

int [EnthalpyToTemperature](#)(real.t &H, real.t &T, real.t &gamma)

### 7.81.2 Member Function Documentation

int E2T ( real.t & H, real.t & T, real.t & gamma )

Calculate temperature from enthalpy.

This member function is to be called in any equation class that needs phase change laws.

Parameters

|     |          |                                              |
|-----|----------|----------------------------------------------|
| in  | $H$      | Enthalpy value                               |
| out | $T$      | Calculated temperature value                 |
| out | $\gamma$ | Maximal slope of the curve $H \rightarrow T$ |

virtual int [EnthalpyToTemperature](#) ( real.t & H, real.t & T, real.t & gamma ) [virtual]

Virtual function to calculate temperature from enthalpy.

This member function must be implemented in any derived class in order to define user's own material laws.

Parameters

|     |          |                                              |
|-----|----------|----------------------------------------------|
| in  | $H$      | Enthalpy value                               |
| out | $T$      | Calculated temperature value                 |
| out | $\gamma$ | Maximal slope of the curve $H \rightarrow T$ |

## 7.82 Point< T\_ > Class Template Reference

Defines a point with arbitrary type coordinates.

### Public Member Functions

- [Point](#) ()  
*Default constructor.*
- [Point](#) (T\_ a, T\_ b=T\_(0), T\_ c=T\_(0))  
*Constructor that assigns a, b to x-, y- and z-coordinates respectively.*
- [Point](#) (const [Point](#)< T\_ > &p)  
*Copy constructor.*
- T\_ & [operator](#)() (size\_t i)  
*Operator (): Non constant version.*
- const T\_ & [operator](#)() (size\_t i) const  
*Operator (): Constant version.*
- T\_ & [operator](#)[] (size\_t i)

- Operator []: Non constant version.*
- `const T_ & operator[] (size_t i) const`  
*Operator []: Constant version.*
- `Point< T_ > & operator+= (const Point< T_ > &p)`  
*Operator +=*
- `Point< T_ > & operator-= (const Point< T_ > &p)`  
*Operator -=*
- `Point< T_ > & operator= (const T_ &a)`  
*Operator =*
- `Point< T_ > & operator+= (const T_ &a)`  
*Operator +=*
- `Point< T_ > & operator-= (const T_ &a)`  
*Operator -=*
- `Point< T_ > & operator*= (const T_ &a)`  
*Operator \*=*
- `Point< T_ > & operator/= (const T_ &a)`  
*Operator /=*
- `bool operator== (const Point< T_ > &p)`  
*Operator ==*
- `bool operator!= (const Point< T_ > &p)`  
*Operator !=*
- `double NNorm () const`  
*Return squared euclidean norm of vector.*
- `double Norm () const`  
*Return norm (length) of vector.*
- `void Normalize ()`  
*Normalize vector.*
- `Point< double > Director (const Point< double > &p) const`  
*Return Director (Normalized vector)*
- `bool isCloseTo (const Point< double > &a, double toler=OFELI_TOLERANCE) const`  
*Return true if current point is close to instance a (up to tolerance toler)*
- `T_ operator, (const Point< T_ > &p) const`  
*Return Dot (scalar) product of two vectors.*

## Public Attributes

- `T_ x`  
*First coordinate.*
- `T_ y`  
*Second coordinate.*
- `T_ z`  
*Third coordinate.*

### 7.82.1 Detailed Description

`template<class T_>class OFELI::Point< T_ >`

Defines a point with arbitrary type coordinates.  
Operators = and () are overloaded.

## Template Parameters

|           |                                                 |
|-----------|-------------------------------------------------|
| <i>T_</i> | Data type (double, float, complex<double>, ...) |
|-----------|-------------------------------------------------|

**7.82.2 Constructor & Destructor Documentation**

**Point ( *T\_ a*, *T\_ b* = *T\_*(0), *T\_ c* = *T\_*(0) )**

Constructor that assigns a, b to x-, y- and z-coordinates respectively.  
Default values for b and c are 0

**7.82.3 Member Function Documentation**

***T\_*& operator() ( *size\_t i* )**

Operator (): Non constant version.  
Values *i* = 1, 2, 3 correspond to x, y and z respectively

**const *T\_*& operator() ( *size\_t i* ) const**

Operator (): Constant version.  
Values *i* = 1, 2, 3 correspond to x, y and z respectively

***T\_*& operator[] ( *size\_t i* )**

Operator []: Non constant version.  
Values *i* = 0, 1, 2 correspond to x, y and z respectively

**const *T\_*& operator[] ( *size\_t i* ) const**

Operator []: Constant version.  
Values *i* = 0, 1, 2 correspond to x, y and z respectively

**Point<*T\_*>& operator+=( *const Point*< *T\_* > &*p* )**

Operator +=  
Add point *p* to current instance

**Point<*T\_*>& operator-=( *const Point*< *T\_* > &*p* )**

Operator -=  
Subtract point *p* from current instance

**Point<*T\_*>& operator= ( *const T\_* &*a* )**

Operator =  
Assign constant *a* to current instance coordinates

**Point<*T\_*>& operator+=( *const T\_* &*a* )**

Operator +=  
Add constant *a* to current instance coordinates

**Point<T\_>& operator-= ( const T\_ & a )**

Operator -=  
Subtract constant a from current instance coordinates

**Point<T\_>& operator\*= ( const T\_ & a )**

Operator \*=  
Multiply constant a by current instance coordinates

**Point<T\_>& operator/= ( const T\_ & a )**

Operator /=  
Divide current instance coordinates by a

**bool operator==( const Point< T\_ > & p )**

Operator ==  
Return true if current instance is equal to p, false otherwise.

**bool operator!=( const Point< T\_ > & p )**

Operator !=  
Return false if current instance is equal to p, true otherwise.

**void Normalize ( )**

Normalize vector.  
Divide vector components by its 2-norm

**bool isCloseTo ( const Point< double > & a, double toler = OFELI\_TOLERANCE ) const**

Return true if current point is close to instance a (up to tolerance toler)  
Default value for toler is the OFELI\_TOLERANCE constant.

**T\_ operator, ( const Point< T\_ > & p ) const**

Return Dot (scalar) product of two vectors.  
A typical use of this operator is double a = (p,q) where p and q are 2 instances of Point<double>  
Parameters

|    |   |                                                            |
|----|---|------------------------------------------------------------|
| in | p | Point instance by which the current instance is multiplied |
|----|---|------------------------------------------------------------|

## 7.83 Point2D< T\_ > Class Template Reference

Defines a 2-D point with arbitrary type coordinates.

### Public Member Functions

- [Point2D](#) ()  
*Default constructor.*
- [Point2D](#) (T\_ a, T\_ b=T\_(0))  
*Constructor that assigns a, b to x-, y- and y-coordinates respectively.*

- **Point2D** (T\_ \*a)  
*Initialize point coordinates with C-array a.*
- **Point2D** (const **Point2D**< T\_ > &pt)  
*Copy constructor.*
- **Point2D** (const **Point**< T\_ > &pt)  
*Copy constructor from class **Point**.*
- T\_ & **operator()** (size\_t i)  
*Operator() : Non constant version.*
- const T\_ & **operator()** (size\_t i) const  
*Operator() : Constant version.*
- T\_ & **operator[]** (size\_t i)  
*Operator []: Non constant version.*
- const T\_ & **operator[]** (size\_t i) const  
*Operator [] Constant version.*
- **Point2D**< T\_ > & **operator=** (const **Point2D**< T\_ > &p)  
*Operator =*
- **Point2D**< T\_ > & **operator+=** (const **Point2D**< T\_ > &p)  
*Operator +=*
- **Point2D**< T\_ > & **operator-=** (const **Point2D**< T\_ > &p)  
*Operator -=*
- **Point2D**< T\_ > & **operator=** (const T\_ &a)  
*Operator =*
- **Point2D**< T\_ > & **operator+=** (const T\_ &a)  
*Operator +=*
- **Point2D**< T\_ > & **operator-=** (const T\_ &a)  
*Operator -=*
- **Point2D**< T\_ > & **operator\*=** (const T\_ &a)  
*Operator \*=*
- **Point2D**< T\_ > & **operator/=** (const T\_ &a)  
*Operator /=*
- bool **operator==** (const **Point2D**< T\_ > &p)  
*Operator ==*
- bool **operator!=** (const **Point2D**< T\_ > &p)  
*Operator !=*
- **real\_t** **CrossProduct** (const **Point2D**< **real\_t** > &lp, const **Point2D**< **real\_t** > &rp)  
*Return Cross product of two vectors lp and rp*
- **real\_t** **NNorm** () const  
*Return squared norm (length) of vector.*
- **real\_t** **Norm** () const  
*Return norm (length) of vector.*
- **Point2D**< **real\_t** > **Director** (const **Point2D**< **real\_t** > &p) const  
*Return Director (Normalized vector)*
- bool **isCloseTo** (const **Point2D**< **real\_t** > &a, **real\_t** toler=**OFELI.TOLERANCE**) const  
*Return true if current point is close to instance a (up to tolerance toler)*

## Public Attributes

- `T_ x`  
*First coordinate of point.*
- `T_ y`  
*Second coordinate of point.*

### 7.83.1 Detailed Description

**template<class T\_>class OFELI::Point2D< T\_ >**

Defines a 2-D point with arbitrary type coordinates.

Operators = and () are overloaded. The actual  
Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.83.2 Constructor & Destructor Documentation

**Point2D ( T\_ a, T\_ b = T\_ (0) )**

Constructor that assigns a, b to x-, y- and y-coordinates respectively.  
Default value for *b* is 0

### 7.83.3 Member Function Documentation

**T\_& operator() ( size\_t i )**

Operator() : Non constant version.  
Values *i* = 1, 2 correspond to x and y respectively

**const T\_& operator() ( size\_t i ) const**

Operator() : Constant version.  
Values *i*=1, 2 correspond to x and y respectively

**T\_& operator[] ( size\_t i )**

Operator[] : Non constant version.  
Values *i*=0, 1 correspond to x and y respectively

**const T\_& operator[] ( size\_t i ) const**

Operator[] Constant version.  
Values *i*=0, 1 correspond to x and y respectively

**Point2D<T\_>& operator= ( const Point2D< T\_ > & p )**

Operator =  
Assign point p to current instance

**Point2D<T\_>& operator+= ( const Point2D< T\_ > & p )**

Operator +=  
Add point p to current instance

**Point2D<T\_>& operator-= ( const Point2D< T\_ > & p )**

Operator -=  
Subtract point p from current instance

**Point2D<T\_>& operator= ( const T\_ & a )**

Operator =  
Assign constant a to current instance coordinates

**Point2D<T\_>& operator+= ( const T\_ & a )**

Operator +=  
Add constant a to current instance coordinates

**Point2D<T\_>& operator-= ( const T\_ & a )**

Operator -=  
Subtract constant a from current instance coordinates

**Point2D<T\_>& operator\*= ( const T\_ & a )**

Operator \*=  
Multiply constant a by current instance coordinates

**Point2D<T\_>& operator/= ( const T\_ & a )**

Operator /=  
Divide current instance coordinates by a

**bool operator== ( const Point2D< T\_ > & p )**

Operator ==  
Return true if current instance is equal to p, false otherwise.

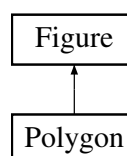
**bool operator!= ( const Point2D< T\_ > & p )**

Operator !=  
Return false if current instance is equal to p, true otherwise.

## 7.84 Polygon Class Reference

To store and treat a polygonal figure.

Inheritance diagram for Polygon:





## Public Member Functions

- `polygon ()`  
*Default constructor.*
- `Polygon (const Vect< Point< real_t > > &v, int code=1)`  
*Constructor.*
- `void setVertices (const Vect< Point< real_t > > &v)`  
*Assign vertices of polygon.*
- `real_t getSignedDistance (const Point< real_t > &p) const`  
*Return signed distance of a given point from the current polygon.*
- `Polygon & operator+= (Point< real_t > a)`  
*Operator +=.*
- `Polygon & operator+= (real_t a)`  
*Operator \*+=.*
- `void setCode (int code)`  
*Choose a code for the domain defined by the figure.*
- `void getSignedDistance (const Grid &g, Vect< real_t > &d) const`  
*Calculate signed distance to current figure with respect to grid points.*
- `real_t dLine (const Point< real_t > &p, const Point< real_t > &a, const Point< real_t > &b) const`  
*Compute signed distance from a line.*

### 7.84.1 Detailed Description

To store and treat a polygonal figure.

### 7.84.2 Constructor & Destructor Documentation

`Polygon ( const Vect< Point< real_t > > &v, int code = 1 )`

Constructor.

Parameters

|                 |                   |                                                                               |
|-----------------|-------------------|-------------------------------------------------------------------------------|
| <code>in</code> | <code>v</code>    | <code>Vect</code> instance containing list of coordinates of polygon vertices |
| <code>in</code> | <code>code</code> | Code to assign to the generated domain (Default value = 1)                    |

### 7.84.3 Member Function Documentation

`void setVertices ( const Vect< Point< real_t > > &v )`

Assign vertices of polygon.

Parameters

|                 |                |                                                                   |
|-----------------|----------------|-------------------------------------------------------------------|
| <code>in</code> | <code>v</code> | Vector containing vertices coordinates in counter clockwise order |
|-----------------|----------------|-------------------------------------------------------------------|

`real_t getSignedDistance ( const Point< real_t > &p ) const` [virtual]

Return signed distance of a given point from the current polygon.

The computed distance is negative if p lies in the polygon, negative if it is outside, and 0 on its boundary

Parameters

|    |     |                                           |
|----|-----|-------------------------------------------|
| in | $p$ | <code>Point&lt;double&gt;</code> instance |
|----|-----|-------------------------------------------|

Reimplemented from [Figure](#).

**`Polygon& operator+= ( Point< real_t > a )`**

Operator +=.

Translate polygon by a vector  $a$

**`Polygon& operator+= ( real_t a )`**

Operator \*.

Scale polygon by a factor  $a$

**`void getSignedDistance ( const Grid & g, Vect< real_t > & d ) const`** [inherited]

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |     |                                                                                                             |
|----|-----|-------------------------------------------------------------------------------------------------------------|
| in | $g$ | <a href="#">Grid</a> instance                                                                               |
| in | $d$ | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector  $d$  doesn't need to be sized before invoking this function

**`real_t dLine ( const Point< real_t > & p, const Point< real_t > & a, const Point< real_t > & b ) const`** [inherited]

Compute signed distance from a line.

Parameters

|    |     |                                                      |
|----|-----|------------------------------------------------------|
| in | $p$ | <a href="#">Point</a> for which distance is computed |
| in | $a$ | First vertex of line                                 |
| in | $b$ | Second vertex of line                                |

Returns

Signed distance

## 7.85 `Prec< T_ >` Class Template Reference

To set a preconditioner.

### Public Member Functions

- [Prec](#) ()  
*Default constructor.*
- [Prec](#) (int type)  
*Constructor that chooses preconditioner.*
- [Prec](#) (const [SpMatrix](#)< T\_ > &A, int type=[DIAG.PREC](#))

- Constructor using matrix of the linear system to precondition.*
- `Prec` (const `Matrix< T_ > *A`, int type=`DIAG.PREC`)  
*Constructor using matrix of the linear system to precondition.*
- `~Prec` ()  
*Destructor.*
- void `setType` (int type)  
*Define preconditioner type.*
- void `setMatrix` (const `Matrix< T_ > *A`)  
*Define pointer to matrix for preconditioning (if this one is abstract)*
- void `setMatrix` (const `SpMatrix< T_ > &A`)  
*Define the matrix for preconditioning.*
- void `solve` (`Vect< T_ > &x`) const  
*Solve a linear system with preconditioning matrix.*
- void `solve` (const `Vect< T_ > &b`, `Vect< T_ > &x`) const  
*Solve a linear system with preconditioning matrix.*
- void `TransSolve` (`Vect< T_ > &x`) const  
*Solve a linear system with transposed preconditioning matrix.*
- void `TransSolve` (const `Vect< T_ > &b`, `Vect< T_ > &x`) const  
*Solve a linear system with transposed preconditioning matrix.*
- `T_ &getPivot` (size\_t i) const  
*Return i-th pivot of preconditioning matrix.*

### 7.85.1 Detailed Description

`template<class T_>class OFELI::Prec< T_ >`

To set a preconditioner.

The preconditioner type is chosen in the constructor

Template Parameters

|                         |                                                 |
|-------------------------|-------------------------------------------------|
| <code>&lt;T_&gt;</code> | Data type (real_t, float, complex<real_t>, ...) |
|-------------------------|-------------------------------------------------|

### 7.85.2 Constructor & Destructor Documentation

`Prec` ( int type )

Constructor that chooses preconditioner.

Parameters

| in | type | Preconditioner type:                                                                                                                                                                                                                                                                                                                                                                                      |
|----|------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|    |      | <ul style="list-style-type: none"> <li>• <code>IDENT.PREC</code>: Identity preconditioner (No preconditioning)</li> <li>• <code>DIAG.PREC</code>: Diagonal preconditioner</li> <li>• <code>DILU.PREC</code>: Diagonal Incomplete factorization preconditioner</li> <li>• <code>ILU.PREC</code>: Incomplete factorization preconditioner</li> <li>• <code>SSOR.PREC</code>: SSOR preconditioner</li> </ul> |

**`Prec ( const SpMatrix< T_ > & A, int type = DIAG_PREC )`**

Constructor using matrix of the linear system to precondition.

Parameters

|                 |             |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | $A$         | Matrix to precondition                                                                                                                                                                                                                                                                                                                                                                                                         |
| <code>in</code> | <i>type</i> | Preconditioner type: <ul style="list-style-type: none"> <li>• <code>IDENT_PREC</code>: Identity preconditioner (No preconditioning)</li> <li>• <code>DIAG_PREC</code>: Diagonal preconditioner</li> <li>• <code>DILU_PREC</code>: Diagonal Incomplete factorization preconditioner</li> <li>• <code>ILU_PREC</code>: Incomplete factorization preconditioner</li> <li>• <code>SSOR_PREC</code>: SSOR preconditioner</li> </ul> |

**`Prec ( const Matrix< T_> * A, int type = DIAG_PREC )`**

Constructor using matrix of the linear system to precondition.

Parameters

|                 |             |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | $A$         | Pointer to abstract <a href="#">Matrix</a> class to precondition                                                                                                                                                                                                                                                                                                                                                               |
| <code>in</code> | <i>type</i> | Preconditioner type: <ul style="list-style-type: none"> <li>• <code>IDENT_PREC</code>: Identity preconditioner (No preconditioning)</li> <li>• <code>DIAG_PREC</code>: Diagonal preconditioner</li> <li>• <code>DILU_PREC</code>: Diagonal Incomplete factorization preconditioner</li> <li>• <code>ILU_PREC</code>: Incomplete factorization preconditioner</li> <li>• <code>SSOR_PREC</code>: SSOR preconditioner</li> </ul> |

### 7.85.3 Member Function Documentation

**`void setType ( int type )`**

Define preconditioner type.

Parameters

|                 |             |                                                                                                                                                                                                                                                                                                                                                                                                                                |
|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <i>type</i> | Preconditioner type: <ul style="list-style-type: none"> <li>• <code>IDENT_PREC</code>: Identity preconditioner (No preconditioning)</li> <li>• <code>DIAG_PREC</code>: Diagonal preconditioner</li> <li>• <code>DILU_PREC</code>: Diagonal Incomplete factorization preconditioner</li> <li>• <code>ILU_PREC</code>: Incomplete factorization preconditioner</li> <li>• <code>SSOR_PREC</code>: SSOR preconditioner</li> </ul> |
|-----------------|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void setMatrix ( const Matrix< T\_ > \* A )**

Define pointer to matrix for preconditioning (if this one is abstract)

Parameters

|    |     |                        |
|----|-----|------------------------|
| in | $A$ | Matrix to precondition |
|----|-----|------------------------|

**void setMatrix ( const SpMatrix< T\_ > & A )**

Define the matrix for preconditioning.

Parameters

|    |     |                                                                      |
|----|-----|----------------------------------------------------------------------|
| in | $A$ | Matrix to precondition (instance of class <a href="#">SpMatrix</a> ) |
|----|-----|----------------------------------------------------------------------|

**void solve ( Vect< T\_ > & x ) const**

Solve a linear system with preconditioning matrix.

Parameters

|        |     |                                                  |
|--------|-----|--------------------------------------------------|
| in,out | $x$ | Right-hand side on input and solution on output. |
|--------|-----|--------------------------------------------------|

**void solve ( const Vect< T\_ > & b, Vect< T\_ > & x ) const**

Solve a linear system with preconditioning matrix.

Parameters

|     |     |                 |
|-----|-----|-----------------|
| in  | $b$ | Right-hand side |
| out | $x$ | Solution vector |

**void TransSolve ( Vect< T\_ > & x ) const**

Solve a linear system with transposed preconditioning matrix.

Parameters

|        |     |                                                  |
|--------|-----|--------------------------------------------------|
| in,out | $x$ | Right-hand side in input and solution in output. |
|--------|-----|--------------------------------------------------|

**void TransSolve ( const Vect< T\_ > & b, Vect< T\_ > & x ) const**

Solve a linear system with transposed preconditioning matrix.

Parameters

|     |     |                        |
|-----|-----|------------------------|
| in  | $b$ | Right-hand side vector |
| out | $x$ | Solution vector        |

## 7.86 Prescription Class Reference

To prescribe various types of data by an algebraic expression. Data may consist in boundary conditions, forces, tractions, fluxes, initial condition. All these data types can be defined through an enumerated variable.

## Public Member Functions

- [Prescription](#) ()  
*Default constructor.*
- [Prescription](#) ([Mesh](#) &mesh, const string &file)  
*Constructor that gives an instance of class [Mesh](#) and the data file name.*
- [~Prescription](#) ()  
*Destructor.*
- int [get](#) (int type, [Vect](#)< [real\\_t](#) > &*v*, [real\\_t](#) time=0, size\_t dof=0)

### 7.86.1 Detailed Description

To prescribe various types of data by an algebraic expression. Data may consist in boundary conditions, forces, tractions, fluxes, initial condition. All these data types can be defined through an enumerated variable.

### 7.86.2 Constructor & Destructor Documentation

**[Prescription](#) ( [Mesh](#) & *mesh*, const string & *file* )**

Constructor that gives an instance of class [Mesh](#) and the data file name.

It reads parameters in [Prescription](#) Format from this file.

Parameters

|    |             |                                           |
|----|-------------|-------------------------------------------|
| in | <i>mesh</i> | <a href="#">Mesh</a> instance             |
| in | <i>file</i> | Name of <a href="#">Prescription</a> file |

### 7.86.3 Member Function Documentation

**int [get](#) ( int *type*, [Vect](#)< [real\\_t](#) > & *v*, [real\\_t](#) *time* = 0, size\_t *dof* = 0 )**

Read data in the given file and stores in a [Vect](#) instance for a chosen DOF. The input value type determines the type of data to read.

Parameters

|    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>type</i> | Type of data to seek. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• BOUNDARY_CONDITION: Read values for (Dirichlet) boundary conditions</li> <li>• BOUNDARY_FORCE: Read values for boundary force (Neumann boundary condition).<br/>The values TRACTION and FLUX have the same effect.</li> <li>• BODY_FORCE: Read values for body (or volume) forces.<br/>The value SOURCE has the same effect.</li> <li>• POINT_FORCE: Read values for pointwise forces</li> <li>• INITIAL_FIELD: Read values for initial solution</li> </ul> |
|----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

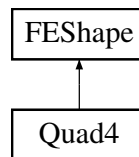


|        |        |                                                                                  |
|--------|--------|----------------------------------------------------------------------------------|
| in,out | $v$    | <a href="#">Vect</a> instance that is instantiated on input and filled on output |
| in     | $time$ | Value of time for which data is read [Default: 0].                               |
| in     | $dof$  | DOF to store (Default is 0: All DOFs are chosen).                                |

## 7.87 Quad4 Class Reference

Defines a 4-node quadrilateral finite element using  $Q_1$  isoparametric interpolation.

Inheritance diagram for Quad4:



### Public Member Functions

- [Quad4](#) ()  
*Default Constructor.*
- [Quad4](#) (const [Element](#) \*element)  
*Constructor when data of [Element](#)  $el$  are given.*
- [Quad4](#) (const [Side](#) \*side)  
*Constructor when data of [Side](#)  $sd$  are given.*
- [~Quad4](#) ()  
*Destructor.*
- void [set](#) (const [Element](#) \*el)  
*Choose element by giving its pointer.*
- void [set](#) (const [Side](#) \*sd)  
*Choose side by giving its pointer.*
- void [setLocal](#) (const [Point](#)< [real\\_t](#) > &s)  
*Initialize local point coordinates in element.*
- [Point](#)< [real\\_t](#) > [DSh](#) (size\_t i) const  
*Return derivatives of shape function of node  $i$  at a given point.*
- [Point](#)< [real\\_t](#) > [Grad](#) (const [LocalVect](#)< [real\\_t](#), 4 > &u, const [Point](#)< [real\\_t](#) > &s)  
*Return gradient of a function defined at element nodes.*
- [real\\_t](#) [getMaxEdgeLength](#) () const  
*Return maximal edge length of quadrilateral.*
- [real\\_t](#) [getMinEdgeLength](#) () const  
*Return minimal edge length of quadrilateral.*
- [real\\_t](#) [Sh](#) (size\_t i) const  
*Return shape function of node  $i$  at given point.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node  $i$  at a given point  $s$ .*
- [real\\_t](#) [getDet](#) () const  
*Return determinant of jacobian.*
- [Point](#)< [real\\_t](#) > [getCenter](#) () const

*Return coordinates of center of element.*

- `Point< real_t > getLocalPoint () const`

*Localize a point in the element.*

- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`

*Localize a point in the element.*

### 7.87.1 Detailed Description

Defines a 4-node quadrilateral finite element using  $Q_1$  isoparametric interpolation.

The reference element is the square  $[-1, 1] \times [-1, 1]$ . The user must take care to the fact that determinant of jacobian and other quantities depend on the point in the reference element where they are calculated. For this, before any utilization of shape functions or jacobian, function `setLocal()` must be invoked.

### 7.87.2 Constructor & Destructor Documentation

**Quad4 ( const Element \* element )**

Constructor when data of `Element` e1 are given.

Parameters

|    |         |                                 |
|----|---------|---------------------------------|
| in | element | Pointer to <code>Element</code> |
|----|---------|---------------------------------|

**Quad4 ( const Side \* side )**

Constructor when data of `Side` sd are given.

Parameters

|    |      |                              |
|----|------|------------------------------|
| in | side | Pointer to <code>Side</code> |
|----|------|------------------------------|

### 7.87.3 Member Function Documentation

**void setLocal ( const Point< real\_t > & s )**

Initialize local point coordinates in element.

Parameters

|    |   |                                                                                                                                                                                   |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | s | <code>Point</code> in the reference element This function computes jacobian, shape functions and their partial derivatives at s. Other member functions only return these values. |
|----|---|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**Point<real\_t> DSh ( size\_t i ) const**

Return derivatives of shape function of node i at a given point.

Member function `setLocal()` must have been called before in order to calculate relevant quantities.

**Point<real\_t> Grad ( const LocalVect< real\_t, 4 > & u, const Point< real\_t > & s )**

Return gradient of a function defined at element nodes.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $u$ | Vector of values at nodes                                                  |
| in | $s$ | Local coordinates (in $[-1, 1]$ ) of point where the gradient is evaluated |

Returns

Value of gradient

Note

If the derivatives of shape functions were not computed before calling this function (by calling `setLocal`), this function will compute them

**real\_t Sh ( size\_t i, Point< real\_t > s ) const** [inherited]

Calculate shape function of node  $i$  at a given point  $s$ .

Parameters

|    |     |                                                                                       |
|----|-----|---------------------------------------------------------------------------------------|
| in | $i$ | Local node label                                                                      |
| in | $s$ | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

Localize a point in the element.

Return actual coordinates where  $s$  are coordinates in the reference element.

## 7.88 Reconstruction Class Reference

To perform various reconstruction operations.

### Public Member Functions

- [Reconstruction](#) ()  
*Default constructor.*
- [Reconstruction](#) (const [Mesh](#) &ms)  
*Constructor using a reference to a [Mesh](#) instance.*
- [~Reconstruction](#) ()

*Destructor.*

- void [setMesh](#) ([Mesh](#) &ms)

*Provide [Mesh](#) instance.*

- void [P0toP1](#) (const [Vect](#)< [real.t](#) > &u, [Vect](#)< [real.t](#) > &v)

*Smooth an elementwise field to obtain a nodewise field by  $L^2$  projection.*

- void [DP1toP1](#) (const [Vect](#)< [real.t](#) > &u, [Vect](#)< [real.t](#) > &v)

*Smooth an Discontinuous  $P_1$  field to obtain a nodewise (Continuous  $P_1$ ) field by  $L^2$  projection.*

### 7.88.1 Detailed Description

To perform various reconstruction operations.

This class enables various reconstruction operations like smoothing, projections, ...

### 7.88.2 Member Function Documentation

**void [P0toP1](#) ( const [Vect](#)< [real.t](#) > &u, [Vect](#)< [real.t](#) > &v )**

Smooth an elementwise field to obtain a nodewise field by  $L^2$  projection.

Parameters

|     |          |                                                                      |
|-----|----------|----------------------------------------------------------------------|
| in  | <i>u</i> | <a href="#">Vect</a> instance that contains field to smooth          |
| out | <i>v</i> | <a href="#">Vect</a> instance that contains on output smoothed field |

**void [DP1toP1](#) ( const [Vect](#)< [real.t](#) > &u, [Vect](#)< [real.t](#) > &v )**

Smooth an Discontinuous  $P_1$  field to obtain a nodewise (Continuous  $P_1$ ) field by  $L^2$  projection.

Parameters

|     |          |                                                                      |
|-----|----------|----------------------------------------------------------------------|
| in  | <i>u</i> | <a href="#">Vect</a> instance that contains field to smooth          |
| out | <i>v</i> | <a href="#">Vect</a> instance that contains on output smoothed field |

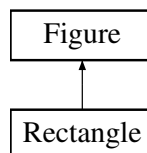
Warning

This function is valid for  $P_1$  triangles (2-D) only.

## 7.89 Rectangle Class Reference

To store and treat a rectangular figure.

Inheritance diagram for Rectangle:



### Public Member Functions

- [Rectangle](#) ()

*Default constructor.*

- [Rectangle](#) (const [Point](#)< [real.t](#) > &bbm, const [Point](#)< [real.t](#) > &bbM, int code=1)

Constructor.

- void **setBoundingBox** (const **Point**< **real.t** > &bbm, const **Point**< **real.t** > &bbM)  
Assign bounding box of the rectangle.
- **Point**< **real.t** > **getBoundingBox1** () const  
Return first point of bounding box.
- **Point**< **real.t** > **getBoundingBox2** () const  
Return second point of bounding box.
- **real.t** **getSignedDistance** (const **Point**< **real.t** > &p) const  
Return signed distance of a given point from the current rectangle.
- **Rectangle** & **operator+=** (**Point**< **real.t** > a)  
Operator +=.
- **Rectangle** & **operator+=** (**real.t** a)  
Operator \*+=.
- void **setCode** (int code)  
Choose a code for the domain defined by the figure.
- void **getSignedDistance** (const **Grid** &g, **Vect**< **real.t** > &d) const  
Calculate signed distance to current figure with respect to grid points.
- **real.t** **dLine** (const **Point**< **real.t** > &p, const **Point**< **real.t** > &a, const **Point**< **real.t** > &b)  
const  
Compute signed distance from a line.

### 7.89.1 Detailed Description

To store and treat a rectangular figure.

### 7.89.2 Constructor & Destructor Documentation

**Rectangle** ( const **Point**< **real.t** > &bbm, const **Point**< **real.t** > &bbM, int code = 1 )

Constructor.

Parameters

|    |      |                                |
|----|------|--------------------------------|
| in | bbm  | Left Bottom point of rectangle |
| in | bbM  | Right Top point of rectangle   |
| in | code | Code to assign to rectangle    |

### 7.89.3 Member Function Documentation

**void setBoundingBox** ( const **Point**< **real.t** > &bbm, const **Point**< **real.t** > &bbM )

Assign bounding box of the rectangle.

Parameters

|    |     |                   |
|----|-----|-------------------|
| in | bbm | Left Bottom point |
| in | bbM | Right Top point   |

**real.t getSignedDistance** ( const **Point**< **real.t** > &p ) const [virtual]

Return signed distance of a given point from the current rectangle.

The computed distance is negative if p lies in the rectangle, negative if it is outside, and 0 on its boundary

Parameters

|    |          |                        |
|----|----------|------------------------|
| in | <i>p</i> | Point<double> instance |
|----|----------|------------------------|

Reimplemented from [Figure](#).

**Rectangle& operator+= ( Point< real.t > a )**

Operator +=.

Translate rectangle by a vector a

**Rectangle& operator+= ( real.t a )**

Operator \*+=.

Scale rectangle by a factor a

**void getSignedDistance ( const Grid & g, Vect< real.t > & d ) const** [inherited]

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |          |                                                                                                             |
|----|----------|-------------------------------------------------------------------------------------------------------------|
| in | <i>g</i> | <a href="#">Grid</a> instance                                                                               |
| in | <i>d</i> | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector d doesn't need to be sized before invoking this function

**real.t dLine ( const Point< real.t > & p, const Point< real.t > & a, const Point< real.t > & b ) const** [inherited]

Compute signed distance from a line.

Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> for which distance is computed |
| in | <i>a</i> | First vertex of line                                 |
| in | <i>b</i> | Second vertex of line                                |

Returns

Signed distance

## 7.90 Side Class Reference

To store and treat finite element sides (edges in 2-D or faces in 3-D)

### Public Types

- enum [SideType](#) {  
[INTERNAL\\_SIDE](#) = 0,  
[EXTERNAL\\_BOUNDARY](#) = 1,  
[INTERNAL\\_BOUNDARY](#) = 2 }

## Public Member Functions

- [Side](#) ()  
*Default Constructor.*
- [Side](#) (size\_t label, const string &shape)  
*Constructor initializing side label and shape.*
- [Side](#) (size\_t label, int shape)  
*Constructor initializing side label and shape.*
- [Side](#) (const [Side](#) &sd)  
*Copy constructor.*
- [~Side](#) ()  
*Destructor.*
- void [Add](#) ([Node](#) \*node)  
*Insert a node at end of list of nodes of side.*
- void [Add](#) ([Edge](#) \*edge)  
*Insert an edge at end of list of edges of side.*
- void [setLabel](#) (size\_t i)  
*Define label of side.*
- void [setFirstDOF](#) (size\_t n)  
*Define First DOF.*
- void [setNbDOF](#) (size\_t nb\_dof)  
*Set number of degrees of freedom (DOF).*
- void [DOF](#) (size\_t i, size\_t dof)  
*Define label of DOF.*
- void [setDOF](#) (size\_t &first\_dof, size\_t nb\_dof)  
*Define number of DOF.*
- void [setCode](#) (size\_t dof, int code)  
*Assign code to a DOF.*
- void [setCode](#) (const string &exp, int code, size\_t dof=1)  
*Define code by a boolean algebraic expression invoking coordinates of side nodes.*
- void [Replace](#) (size\_t label, [Node](#) \*node)  
*Replace a node at a given local label.*
- void [Add](#) ([Element](#) \*el)  
*Set pointer to neighbor element.*
- void [set](#) ([Element](#) \*el, size\_t i)  
*Set pointer to neighbor element.*
- void [setNode](#) (size\_t i, [Node](#) \*node)  
*Assign a node given by its pointer as the i-th node of side.*
- int [getShape](#) () const  
*Return side's shape.*
- size\_t [getLabel](#) () const  
*Return label of side.*
- size\_t [n](#) () const  
*Return label of side.*
- size\_t [getNbNodes](#) () const  
*Return number of side nodes.*
- size\_t [getNbVertices](#) () const

- Return number of side vertices.*

  - `size_t getNbEq () const`
- Return number of side equations.*

  - `size_t getNbDOF () const`
- Return number of DOF.*

  - `int getCode (size_t dof=1) const`
- Return code for a given DOF of node.*

  - `size_t getDOF (size_t i) const`
- Return label of i-th dof.*

  - `size_t getFirstDOF () const`
- Return label of first dof of node.*

  - `Node * getPtrNode (size_t i) const`
- Return pointer to node of local label i.*

  - `Node * operator() (size_t i) const`
- Operator ().*

  - `size_t getNodeLabel (size_t i) const`
- Return global label of node with given local label.*

  - `Element * getNeighborElement (size_t i) const`
- Return pointer to i-th side neighboring element.*

  - `Element * getOtherNeighborElement (Element *el) const`
- Return pointer to other neighboring element than given one.*

  - `Point< real_t > getNormal () const`
- Return normal vector to side.*

  - `Point< real_t > getUnitNormal () const`
- Return unit normal vector to side.*

  - `int isOnBoundary () const`
- Boundary side or not.*

  - `void setOnBoundary ()`
- Say that the side is on the boundary.*

  - `real_t getMeasure () const`
- Return measure of side.*

  - `size_t Contains (const Node *nd) const`
- Say if a given node belongs to current side.*

  - `void setActive (bool opt=true)`
- Set side is active (default) or not if argument is false*

  - `bool isActive () const`
- Return true or false whether side is active or not.*

  - `int getLevel () const`
- Return side level Side level increases when side is refined (starting from 0). If the level is 0, then the element has no father.*

  - `void setChild (Side *sd)`
- Assign side as child of current one and assign current side as father.*

  - `Side * getParent () const`
- Return pointer to parent side Return null if no parent.*

  - `Side * getChild (size_t i) const`
- Return pointer to i-th child side Returns null pointer is no childs.*

  - `size_t getNbChilds () const`
- Return number of children of side.*



### 7.90.1 Detailed Description

To store and treat finite element sides (edges in 2-D or faces in 3-D)

Defines a side of a finite element mesh. The sides are given in particular by their shapes and a list of nodes. Each node can be accessed by the member function [getPtrNode\(\)](#). The string defining the element shape must be chosen according to the following list:

### 7.90.2 Member Enumeration Documentation

#### enum SideType

To select side type (boundary side or not).

Enumerator

*INTERNAL\_SIDE* Internal side

*EXTERNAL\_BOUNDARY* [Side](#) on external boundary

*INTERNAL\_BOUNDARY* [Side](#) on internal boundary

### 7.90.3 Constructor & Destructor Documentation

**Side** ( *size\_t label*, *const string & shape* )

Constructor initializing side label and shape.

Parameters

|           |              |                                        |
|-----------|--------------|----------------------------------------|
| <i>in</i> | <i>label</i> | Label to assign to side.               |
| <i>in</i> | <i>shape</i> | Shape of side (See class description). |

**Side** ( *size\_t label*, *int shape* )

Constructor initializing side label and shape.

Parameters

|           |              |                                                           |
|-----------|--------------|-----------------------------------------------------------|
| <i>in</i> | <i>label</i> | to assign to side.                                        |
| <i>in</i> | <i>shape</i> | of side (See enum ElementShape in <a href="#">Mesh</a> ). |

### 7.90.4 Member Function Documentation

**void DOF** ( *size\_t i*, *size\_t dof* )

Define label of DOF.

Parameters

|           |            |           |
|-----------|------------|-----------|
| <i>in</i> | <i>i</i>   | DOF index |
| <i>in</i> | <i>dof</i> | Its label |

**void setDOF** ( *size\_t & first\_dof*, *size\_t nb\_dof* )

Define number of DOF.

Parameters

|               |                  |                                                    |
|---------------|------------------|----------------------------------------------------|
| <b>in,out</b> | <i>first_dof</i> | Label of the first DOF in input that is actualized |
| <b>in</b>     | <i>nb_dof</i>    | Number of DOF                                      |

**void setCode ( size\_t dof, int code )**

Assign code to a DOF.

Parameters

|           |             |                               |
|-----------|-------------|-------------------------------|
| <b>in</b> | <i>dof</i>  | DOF to which code is assigned |
| <b>in</b> | <i>code</i> | Code to assign                |

**void setCode ( const string & exp, int code, size\_t dof = 1 )**

Define code by a boolean algebraic expression invoking coordinates of side nodes.

Parameters

|           |             |                                                            |
|-----------|-------------|------------------------------------------------------------|
| <b>in</b> | <i>exp</i>  | Boolean algebraic expression as required by fparser        |
| <b>in</b> | <i>code</i> | Code to assign to node if the algebraic expression is true |
| <b>in</b> | <i>dof</i>  | Degree of Freedom for which code is assigned [Default: 1]  |

**void Add ( Element \* el )**

Set pointer to neighbor element.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>el</i> | Pointer to element to add as a neighbor element |
|-----------|-----------|-------------------------------------------------|

Remarks

This function adds the pointer *e1* only if this one is not a null pointer

**void set ( Element \* el, size\_t i )**

Set pointer to neighbor element.

Parameters

|           |           |                                                 |
|-----------|-----------|-------------------------------------------------|
| <b>in</b> | <i>el</i> | Pointer to element to set as a neighbor element |
| <b>in</b> | <i>i</i>  | Local number of neighbor element                |

Remarks

This function differs from the Add by the fact that the local label of neighbor element is given

**int getCode ( size\_t dof = 1 ) const**

Return code for a given DOF of node.

Parameters

|           |            |                                                |
|-----------|------------|------------------------------------------------|
| <i>in</i> | <i>dof</i> | Local label of degree of freedom. [Default: 1] |
|-----------|------------|------------------------------------------------|

**Node\* operator() ( size\_t *i* ) const**

Operator ().

Return pointer to node of local label *i*.

**Element\* getNeighborElement ( size\_t *i* ) const**

Return pointer to *i*-th side neighboring element.

Parameters

|           |          |                                                            |
|-----------|----------|------------------------------------------------------------|
| <i>in</i> | <i>i</i> | Local label of neighbor element (must be equal to 1 or 2). |
|-----------|----------|------------------------------------------------------------|

**Element\* getOtherNeighborElement ( Element \* *el* ) const**

Return pointer to other neighboring element than given one.

Parameters

|           |           |                                     |
|-----------|-----------|-------------------------------------|
| <i>in</i> | <i>el</i> | Pointer to a given neighbor element |
|-----------|-----------|-------------------------------------|

Remarks

If the side is on the boundary this function returns null pointer

**Point<real\_t> getNormal ( ) const**

Return normal vector to side.

The normal vector is oriented from the first neighbor element to the second one.

Warning

The norm of this vector is equal to the measure of the side (length of the edge in 2-D and area of the face in 3-D), and To get the unit normal, use rather the member function `getUnitNormal`.

**Point<real\_t> getUnitNormal ( ) const**

Return unit normal vector to side.

The unit normal vector is oriented from the first neighbor element to the second one.

Remarks

The norm of this vector is equal to one.

**int isOnBoundary ( ) const**

Boundary side or not.

Returns 1 or -1 if side is on boundary Depending on whether the first or the second neighbor element is defined Returns 0 if side is an inner one

Remarks

This member function is valid only if member function `Mesh::getAllSides()` or `Mesh::getBoundarySides()` has been called before.

**real\_t getMeasure ( ) const**

Return measure of side.

This member function returns length or area of side. In case of quadrilaterals it returns determinant of Jacobian of mapping between reference and actual side

**size\_t Contains ( const Node \* nd ) const**

Say if a given node belongs to current side.

Parameters

|    |    |                          |
|----|----|--------------------------|
| in | nd | Pointer to searched node |
|----|----|--------------------------|

Returns

index (local label) of node if found, 0 if not

**void setChild ( Side \* sd )**

Assign side as child of current one and assign current side as father.

This function is principally used when refining is invoked (*e.g.* for mesh adaption)

Parameters

|    |    |                           |
|----|----|---------------------------|
| in | sd | Pointer to side to assign |
|----|----|---------------------------|

## 7.91 SideList Class Reference

Class to construct a list of sides having some common properties.

### Public Member Functions

- [SideList](#) ([Mesh](#) &ms)  
*Constructor using a [Mesh](#) instance.*
- [~SideList](#) ()  
*Destructor.*
- void [selectCode](#) (int code, int dof=1)  
*Select sides having a given code for a given degree of freedom.*
- void [unselectCode](#) (int code, int dof=1)  
*Unselect sides having a given code for a given degree of freedom.*
- size\_t [getNbSides](#) () const  
*Return number of selected sides.*
- void [top](#) ()  
*Reset list of sides at its top position (Non constant version)*
- void [top](#) () const  
*Reset list of sides at its top position (Constant version)*
- [Side](#) \* [get](#) ()  
*Return pointer to current side and move to next one (Non constant version)*
- [Side](#) \* [get](#) () const  
*Return pointer to current side and move to next one (Constant version)*

### 7.91.1 Detailed Description

Class to construct a list of sides having some common properties.

This class enables choosing multiple selection criteria by using function `select...`. However, the intersection of these properties must be empty.

### 7.91.2 Member Function Documentation

**void selectCode ( int code, int dof = 1 )**

Select sides having a given code for a given degree of freedom.

Parameters

|    |      |                                      |
|----|------|--------------------------------------|
| in | code | Code that sides share                |
| in | dof  | Degree of Freedom label [Default: 1] |

**void unselectCode ( int code, int dof = 1 )**

Unselect sides having a given code for a given degree of freedom.

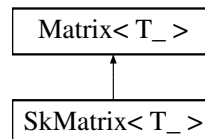
Parameters

|    |      |                                      |
|----|------|--------------------------------------|
| in | code | Code of sides to exclude             |
| in | dof  | Degree of Freedom label [Default: 1] |

## 7.92 SkMatrix< T\_ > Class Template Reference

To handle square matrices in skyline storage format.

Inheritance diagram for SkMatrix< T\_ >:



### Public Member Functions

- [SkMatrix](#) ()  
*Default constructor.*
- [SkMatrix](#) (size\_t size, int is\_diagonal=false)  
*Constructor that initializes a dense symmetric matrix.*
- [SkMatrix](#) (Mesh &mesh, size\_t dof=0, int is\_diagonal=false)  
*Constructor using mesh to initialize skyline structure of matrix.*
- [SkMatrix](#) (const Vect< size\_t > &ColHt)  
*Constructor that initializes skyline structure of matrix using vector of column heights.*
- [SkMatrix](#) (const SkMatrix< T\_ > &m)  
*Copy Constructor.*
- [~SkMatrix](#) ()  
*Destructor.*
- void [setMesh](#) (Mesh &mesh, size\_t dof=0)

- Determine mesh graph and initialize matrix.*
- void **setSkyline** (**Mesh** &mesh)
- Determine matrix structure.*
- void **setDiag** ()
- Store diagonal entries in a separate internal vector.*
- void **setDOF** (size\_t i)
- Choose DOF to activate.*
- void **set** (size\_t i, size\_t j, const T\_ &val)
- Assign a value to an entry of the matrix.*
- void **Axpy** (T\_ a, const **SkMatrix**< T\_ > &m)
- Add to matrix the product of a matrix by a scalar.*
- void **Axpy** (T\_ a, const **Matrix**< T\_ > \*m)
- Add to matrix the product of a matrix by a scalar.*
- void **MultAdd** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const
- Multiply matrix by vector  $x$  and add to  $y$ .*
- void **TMultAdd** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const
- Multiply transpose of matrix by vector  $x$  and add to  $y$ .*
- void **MultAdd** (T\_ a, const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const
- Multiply matrix by a vector and add to another one.*
- void **Mult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const
- Multiply matrix by vector  $x$  and save in  $y$ .*
- void **TMult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const
- Multiply transpose of matrix by vector  $x$  and save in  $y$ .*
- void **add** (size\_t i, size\_t j, const T\_ &val)
- Add a constant value to an entry of the matrix.*
- size\_t **getColHeight** (size\_t i) const
- Return column height.*
- T\_ **operator()** (size\_t i, size\_t j) const
- Operator () (Constant version).*
- T\_ & **operator()** (size\_t i, size\_t j)
- Operator () (Non constant version).*
- void **DiagPrescribe** (**Mesh** &mesh, **Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)
- Impose an essential boundary condition.*
- void **DiagPrescribe** (**Vect**< T\_ > &b, const **Vect**< T\_ > &u, int flag=0)
- Impose an essential boundary condition using the **Mesh** instance provided by the constructor.*
- **SkMatrix**< T\_ > & **operator=** (const **SkMatrix**< T\_ > &m)
- Operator =.*
- **SkMatrix**< T\_ > & **operator=** (const T\_ &x)
- Operator =.*
- **SkMatrix**< T\_ > & **operator+=** (const **SkMatrix**< T\_ > &m)
- Operator +=.*
- **SkMatrix**< T\_ > & **operator+=** (const T\_ &x)
- Operator +=.*
- **SkMatrix**< T\_ > & **operator\*=** (const T\_ &x)
- Operator \*.*
- int **setLU** ()

- Factorize the matrix (LU factorization)
- int **solve** (Vect< T\_ > &b)
  - Solve linear system.
- int **solve** (const Vect< T\_ > &b, Vect< T\_ > &x)
  - Solve linear system.
- T\_ \* **get** () const
  - Return C-Array.
- T\_ **get** (size\_t i, size\_t j) const
  - Return entry (i, j) of matrix if this one is stored, 0 else.
- size\_t **getNbRows** () const
  - Return number of rows.
- size\_t **getNbColumns** () const
  - Return number of columns.
- void **setPenal** (real\_t p)
  - Set Penalty Parameter (For boundary condition prescription).
- void **setDiagonal** ()
  - Set the matrix as diagonal.
- void **setDiagonal** (Mesh &mesh)
  - Initialize matrix storage in the case where only diagonal terms are stored.
- T\_ **getDiag** (size\_t k) const
  - Return k-th diagonal entry of matrix.
- size\_t **size** () const
  - Return matrix dimension (Number of rows and columns).
- void **Assembly** (const Element &el, T\_ \*a)
  - Assembly of element matrix into global matrix.
- void **Assembly** (const Element &el, const DMatrix< T\_ > &a)
  - Assembly of element matrix into global matrix.
- void **Assembly** (const Side &sd, T\_ \*a)
  - Assembly of side matrix into global matrix.
- void **Assembly** (const Side &sd, const DMatrix< T\_ > &a)
  - Assembly of side matrix into global matrix.
- void **Prescribe** (Vect< T\_ > &b, const Vect< T\_ > &u, int flag=0)
  - Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.
- void **Prescribe** (int dof, int code, Vect< T\_ > &b, const Vect< T\_ > &u, int flag=0)
  - Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.
- void **Prescribe** (Vect< T\_ > &b, int flag=0)
  - Impose by a penalty method a homogeneous (=0) essential boundary condition.
- void **Prescribe** (size\_t dof, Vect< T\_ > &b, const Vect< T\_ > &u, int flag=0)
  - Impose by a penalty method an essential boundary condition when only one DOF is treated.
- void **PrescribeSide** ()
  - Impose by a penalty method an essential boundary condition when DOFs are supported by sides.
- virtual int **Factor** ()=0
  - Factorize matrix. Available only if the storage class enables it.
- int **FactorAndSolve** (Vect< T\_ > &b)
  - Factorize matrix and solve the linear system.
- int **FactorAndSolve** (const Vect< T\_ > &b, Vect< T\_ > &x)

*Factorize matrix and solve the linear system.*

- `size_t getLength () const`  
*Return number of stored terms in matrix.*
- `int isDiagonal () const`  
*Say if matrix is diagonal or not.*
- `int isFactorized () const`  
*Say if matrix is factorized or not.*
- `virtual size_t getColInd (size_t i) const`  
*Return Column index for column  $i$  (See the description for class `SpMatrix`).*
- `virtual size_t getRowPtr (size_t i) const`  
*Return Row pointer for row  $i$  (See the description for class `SpMatrix`).*
- `T_ operator() (size_t i) const`  
*Operator  $()$  with one argument (Constant version).*
- `T_ & operator() (size_t i)`  
*Operator  $()$  with one argument (Non Constant version).*
- `T_ & operator[] (size_t k)`  
*Operator  $[]$  (Non constant version).*
- `T_ operator[] (size_t k) const`  
*Operator  $[]$  (Constant version).*
- `Matrix & operator+= (const Matrix< T_ > &m)`  
*Operator  $+=$ .*
- `Matrix & operator-= (const Matrix< T_ > &m)`  
*Operator  $-=$ .*
- `Matrix & operator-= (const T_ &x)`  
*Operator  $-=$ .*

### 7.92.1 Detailed Description

**template<class T\_>class OFELI::SkMatrix< T\_ >**

To handle square matrices in skyline storage format.

This template class allows storing and manipulating a matrix in skyline storage format.

The matrix entries are stored in 2 vectors column by column as in the following example:

```

/ \ / \
10 .		u0 u1 0 0 u7
11 12 .		u2 u3 0 u8
0 13 14 u4 u5 u9
0 0 15 16		u6 u10
17 18 19 110 111		u11
\ / \ /

```

Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.92.2 Constructor & Destructor Documentation

**SkMatrix ( )**

Default constructor.

Initializes a zero-dimension matrix



**SkMatrix** ( **size\_t** *size*, **int** *is\_diagonal* = *false* )

Constructor that initializes a dense symmetric matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|           |                    |                                                                     |
|-----------|--------------------|---------------------------------------------------------------------|
| <b>in</b> | <i>size</i>        | Number of matrix rows (and columns).                                |
| <b>in</b> | <i>is_diagonal</i> | Boolean to select if the matrix is diagonal or not [Default: false] |

**SkMatrix ( Mesh & mesh, size.t dof = 0, int is\_diagonal = false )**

Constructor using mesh to initialize skyline structure of matrix.

Parameters

|           |                    |                                                                                                                                                                                                                                             |
|-----------|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>mesh</i>        | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| <b>in</b> | <i>dof</i>         | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |
| <b>in</b> | <i>is_diagonal</i> | Boolean argument to say is the matrix is actually a diagonal matrix or not.                                                                                                                                                                 |

**SkMatrix ( const Vect< size.t > & ColHt )**

Constructor that initializes skyline structure of matrix using vector of column heights.

Parameters

|           |              |                                                                     |
|-----------|--------------|---------------------------------------------------------------------|
| <b>in</b> | <i>ColHt</i> | <a href="#">Vect</a> instance that contains rows lengths of matrix. |
|-----------|--------------|---------------------------------------------------------------------|

### 7.92.3 Member Function Documentation

**void setMesh ( Mesh & mesh, size.t dof = 0 )**

Determine mesh graph and initialize matrix.

This member function is called by constructor with the same arguments

Parameters

|           |             |                                                                                                                                                                                                                                             |
|-----------|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>in</b> | <i>mesh</i> | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| <b>in</b> | <i>dof</i>  | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |

**void setSkyline ( Mesh & mesh )**

Determine matrix structure.

This member function calculates matrix structure using a [Mesh](#) instance.

Parameters

|           |             |                               |
|-----------|-------------|-------------------------------|
| <b>in</b> | <i>mesh</i> | <a href="#">Mesh</a> instance |
|-----------|-------------|-------------------------------|

**void setDOF ( size.t i )**

Choose DOF to activate.

This function is available only if variable dof is equal to 1 in the constructor

Parameters

|    |          |                  |
|----|----------|------------------|
| in | <i>i</i> | Index of the DOF |
|----|----------|------------------|

**void set ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Assign a value to an entry of the matrix.

Parameters

|    |            |                                                   |
|----|------------|---------------------------------------------------|
| in | <i>i</i>   | Row index (starting at i=1)                       |
| in | <i>j</i>   | Column index (starting at i=1)                    |
| in | <i>val</i> | Value to assign to entry a( <i>i</i> , <i>j</i> ) |

Implements [Matrix< T\\_ >](#).

**void Axy ( T\_ *a*, const SkMatrix< T\_ > & *m* )**

Add to matrix the product of a matrix by a scalar.

Parameters

|    |          |                                                                                 |
|----|----------|---------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                           |
| in | <i>m</i> | Matrix by which <i>a</i> is multiplied. The result is added to current instance |

**void Axy ( T\_ *a*, const Matrix< T\_ > \* *m* )** [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |          |                                                                                 |
|----|----------|---------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                           |
| in | <i>m</i> | Matrix by which <i>a</i> is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *x* and add to *y*.

Parameters

|        |          |                                                                      |
|--------|----------|----------------------------------------------------------------------|
| in     | <i>x</i> | Vector to multiply by matrix                                         |
| in,out | <i>y</i> | Vector to add to the result. <i>y</i> contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void TMultAdd ( const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const**

Multiply transpose of matrix by vector *x* and add to *y*.

Parameters

|        |          |                                                                      |
|--------|----------|----------------------------------------------------------------------|
| in     | <i>x</i> | Vector to multiply by matrix                                         |
| in,out | <i>y</i> | Vector to add to the result. <i>y</i> contains on output the result. |

**void MultAdd ( T\_ *a*, const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by a vector and add to another one.

Parameters

|        |     |                                                               |
|--------|-----|---------------------------------------------------------------|
| in     | $a$ | Constant to multiply by matrix                                |
| in     | $x$ | Vector to multiply by matrix                                  |
| in,out | $y$ | Vector to add to the result. y contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void Mult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply matrix by vector x and save in y.

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $x$ | Vector to multiply by matrix               |
| out | $y$ | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void TMult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply transpose of matrix by vector x and save in y.

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $x$ | Vector to multiply by matrix               |
| out | $y$ | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void add ( size.t i, size.t j, const T\_ & val )** [virtual]

Add a constant value to an entry of the matrix.

Parameters

|    |       |                                  |
|----|-------|----------------------------------|
| in | $i$   | Row index                        |
| in | $j$   | Column index                     |
| in | $val$ | Constant value to add to a(i, j) |

Implements [Matrix< T\\_ >](#).

**size.t getColHeight ( size.t i ) const**

Return column height.

Column height at entry i is returned.

**T\_ operator() ( size.t i, size.t j ) const** [virtual]

Operator () (Constant version).

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**T\_& operator() ( size.t i, size.t j )** [virtual]

Operator () (Non constant version).

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**void DiagPrescribe ( Mesh & *mesh*, Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**

Impose an essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. It can be modified by member function **setPenal(..)**.

Parameters

|    |             |                                                                                                                                                 |
|----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh</i> | <a href="#">Mesh</a> instance from which information is extracted.                                                                              |
| in | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed.                                                |
| in | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void DiagPrescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**

Impose an essential boundary condition using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. It can be modified by member function **setPenal(..)**.

Parameters

|    |             |                                                                                                                                                 |
|----|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed.                                                |
| in | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**SkMatrix<T\_>& operator= ( const SkMatrix< T\_ > & *m* )**

Operator =.

Copy matrix *m* to current matrix instance.

**SkMatrix<T\_>& operator= ( const T\_ & *x* )**

Operator =.

define the matrix as a diagonal one with all diagonal entries equal to *x*.

**SkMatrix<T\_>& operator+= ( const SkMatrix< T\_ > & *m* )**

Operator +=.

Add matrix *m* to current matrix instance.

**SkMatrix<T\_>& operator+= ( const T\_ & x )**

Operator +=.

Add constant value x to matrix entries.

**SkMatrix<T\_>& operator\*= ( const T\_ & x )**

Operator \*.

Premultiply matrix entries by constant value x.

**int setLU ( )**

Factorize the matrix (LU factorization)

LU factorization of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- 0 if factorization was normally performed,
- n if the n-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

**int solve ( Vect< T\_ > & b ) [virtual]**

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- n if the n-th pivot is null.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LU decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLU realizes the factorization step only.

Parameters

|     |     |                                                              |
|-----|-----|--------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side. |
| out | $x$ | <a href="#">Vect</a> instance that contains solution         |

Returns

- 0 if solution was normally performed,
- $n$  if the  $n$ -th pivot is null.

**T\_\* get ( ) const**

Return C-Array.

Skyline of matrix is stored row by row.

**void setDiagonal ( Mesh & mesh )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t k ) const** [inherited]

Return  $k$ -th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & el, T\_\* a )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |      |                                             |
|----|------|---------------------------------------------|
| in | $el$ | Pointer to element instance                 |
| in | $a$  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & el, const DMatrix< T\_ > & a )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |      |                                                                      |
|----|------|----------------------------------------------------------------------|
| in | $el$ | Pointer to element instance                                          |
| in | $a$  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & sd, T\_\* a )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                                |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                                   |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                               |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =0, default value). |

**void Prescribe ( int *dof*, int *code*, Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                                |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                                             |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                                          |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                                   |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                               |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =0, default value). |



**void Prescribe ( Vect< T\_ > & b, int flag = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                                 |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that conatins imposed valued at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage cass enables it.

Parameters

|        |          |                                                                                             |
|--------|----------|---------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|--------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |     |                                                             |
|-----|-----|-------------------------------------------------------------|
| in  | $b$ | <a href="#">Vect</a> instance that contains right-hand side |
| out | $x$ | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- $n$  if the  $n$ -th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator () with one argument (Constant version).

Returns  $i$ -th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |     |             |
|----|-----|-------------|
| in | $i$ | entry index |
|----|-----|-------------|

**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns  $i$ -th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |     |             |
|----|-----|-------------|
| in | $i$ | entry index |
|----|-----|-------------|

**T\_& operator[] ( size\_t k )** [inherited]

Operator [] (Non constant version).

Returns  $k$ -th stored element in matrix Index  $k$  starts at 0.

**T\_ operator[] ( size\_t k ) const** [inherited]

Operator [] (Constant version).

Returns  $k$ -th stored element in matrix Index  $k$  starts at 0.

**Matrix& operator+= ( const Matrix< T\_ > & m )** [inherited]

Operator +=.

Add matrix  $m$  to current matrix instance.

**Matrix& operator-= ( const Matrix< T\_ > & m )** [inherited]

Operator -=.

Subtract matrix  $m$  from current matrix instance.

**Matrix& operator-= ( const T\_ & x )** [inherited]

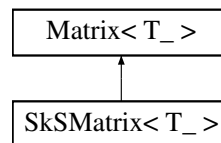
Operator -=.

Subtract constant value x from all matrix entries.

## 7.93 SkSMMatrix< T\_ > Class Template Reference

To handle symmetric matrices in skyline storage format.

Inheritance diagram for SkSMMatrix< T\_ >:



### Public Member Functions

- **SkSMMatrix** ()  
*Default constructor.*
- **SkSMMatrix** (size\_t size, int is\_diagonal=false)  
*Constructor that initializes a dense symmetric matrix.*
- **SkSMMatrix** (Mesh &mesh, size\_t dof=0, int is\_diagonal=false)  
*Constructor using mesh to initialize skyline structure of matrix.*
- **SkSMMatrix** (const Vect< size\_t > &ColHt)  
*Constructor that initializes skyline structure of matrix using vector of column height.*
- **SkSMMatrix** (const Vect< size\_t > &I, const Vect< size\_t > &J, int opt=1)  
*Constructor for a square matrix using non zero row and column indices.*
- **SkSMMatrix** (const Vect< size\_t > &I, const Vect< size\_t > &J, const Vect< T\_ > &a, int opt=1)  
*Constructor for a square matrix using non zero row and column indices.*
- **SkSMMatrix** (const SkSMMatrix< T\_ > &m)  
*Copy Constructor.*
- **~SkSMMatrix** ()  
*Destructor.*
- void **setMesh** (Mesh &mesh, size\_t dof=0)  
*Determine mesh graph and initialize matrix.*
- void **setSkyline** (Mesh &mesh)  
*Determine matrix structure.*
- void **setDiag** ()  
*Store diagonal entries in a separate internal vector.*
- void **set** (size\_t i, size\_t j, const T\_ &val)  
*Assign a value to an entry of the matrix.*
- void **Axpy** (T\_ a, const SkSMMatrix< T\_ > &m)  
*Add to matrix the product of a matrix by a scalar.*
- void **Axpy** (T\_ a, const Matrix< T\_ > \*m)  
*Add to matrix the product of a matrix by a scalar.*
- void **MultAdd** (const Vect< T\_ > &x, Vect< T\_ > &y) const  
*Multiply matrix by vector x and add to y.*

- void **MultAdd** (T\_ a, const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const  
*Multiply matrix by vector  $a \cdot x$  and add to  $y$ .*
- void **Mult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const  
*Multiply matrix by vector  $x$  and save in  $y$*
- void **TMult** (const **Vect**< T\_ > &x, **Vect**< T\_ > &y) const  
*Multiply transpose of matrix by vector  $x$  and save in  $y$ .*
- void **add** (size\_t i, size\_t j, const T\_ &val)  
*Add a constant to an entry of the matrix.*
- size\_t **getColHeight** (size\_t i) const  
*Return column height.*
- **Vect**< T\_ > **getColumn** (size\_t j) const  
*Get  $j$ -th column vector.*
- **Vect**< T\_ > **getRow** (size\_t i) const  
*Get  $i$ -th row vector.*
- T\_ & **operator()** (size\_t i, size\_t j)  
*Operator () (Non constant version).*
- T\_ **operator()** (size\_t i, size\_t j) const  
*Operator () (Constant version).*
- **SkSMatrix**< T\_ > & **operator=** (const **SkSMatrix**< T\_ > &m)  
*Operator =.*
- **SkSMatrix**< T\_ > & **operator=** (const T\_ &x)  
*Operator =.*
- **SkSMatrix**< T\_ > & **operator+=** (const **SkSMatrix**< T\_ > &m)  
*Operator +=.*
- **SkSMatrix**< T\_ > & **operator\*=** (const T\_ &x)  
*Operator \*=.*
- int **setLDLt** ()  
*Factorize matrix (LDLt (Crout) factorization).*
- int **solveLDLt** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve a linear system using the LDLt (Crout) factorization.*
- int **solve** (**Vect**< T\_ > &b)  
*Solve linear system.*
- int **solve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve linear system.*
- T\_ \* **get** () const  
*Return C-Array.*
- void **set** (size\_t i, T\_ x)  
*Assign a value to the  $i$ -th entry of C-array containing matrix.*
- T\_ **get** (size\_t i, size\_t j) const  
*Return entry  $(i, j)$  of matrix if this one is stored, 0 else.*
- size\_t **getNbRows** () const  
*Return number of rows.*
- size\_t **getNbColumns** () const  
*Return number of columns.*
- void **setPenal** (real\_t p)  
*Set Penalty Parameter (For boundary condition prescription).*

- void [setDiagonal](#) ()  
*Set the matrix as diagonal.*
- void [setDiagonal](#) ([Mesh](#) &mesh)  
*Initialize matrix storage in the case where only diagonal terms are stored.*
- T\_ [getDiag](#) (size\_t k) const  
*Return k-th diagonal entry of matrix.*
- size\_t [size](#) () const  
*Return matrix dimension (Number of rows and columns).*
- void [Assembly](#) (const [Element](#) &el, T\_ \*a)  
*Assembly of element matrix into global matrix.*
- void [Assembly](#) (const [Element](#) &el, const [DMatrix](#)< T\_ > &a)  
*Assembly of element matrix into global matrix.*
- void [Assembly](#) (const [Side](#) &sd, T\_ \*a)  
*Assembly of side matrix into global matrix.*
- void [Assembly](#) (const [Side](#) &sd, const [DMatrix](#)< T\_ > &a)  
*Assembly of side matrix into global matrix.*
- void [Prescribe](#) ([Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.*
- void [Prescribe](#) (int dof, int code, [Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- void [Prescribe](#) ([Vect](#)< T\_ > &b, int flag=0)  
*Impose by a penalty method a homogeneous (=0) essential boundary condition.*
- void [Prescribe](#) (size\_t dof, [Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u, int flag=0)  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- void [PrescribeSide](#) ()  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- virtual int [Factor](#) ()=0  
*Factorize matrix. Available only if the storage class enables it.*
- int [FactorAndSolve](#) ([Vect](#)< T\_ > &b)  
*Factorize matrix and solve the linear system.*
- int [FactorAndSolve](#) (const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Factorize matrix and solve the linear system.*
- size\_t [getLength](#) () const  
*Return number of stored terms in matrix.*
- int [isDiagonal](#) () const  
*Say if matrix is diagonal or not.*
- int [isFactorized](#) () const  
*Say if matrix is factorized or not.*
- virtual size\_t [getColInd](#) (size\_t i) const  
*Return Column index for column i (See the description for class [SpMatrix](#)).*
- virtual size\_t [getRowPtr](#) (size\_t i) const  
*Return Row pointer for row i (See the description for class [SpMatrix](#)).*
- T\_ [operator\(\)](#) (size\_t i) const  
*Operator () with one argument (Constant version).*
- T\_ & [operator\(\)](#) (size\_t i)  
*Operator () with one argument (Non Constant version).*

- `T_ & operator[] (size_t k)`  
*Operator [] (Non constant version).*
- `T_ operator[] (size_t k) const`  
*Operator [] (Constant version).*
- `Matrix & operator+= (const Matrix< T_ > &m)`  
*Operator +=.*
- `Matrix & operator+= (const T_ &x)`  
*Operator +=.*
- `Matrix & operator-= (const Matrix< T_ > &m)`  
*Operator -=.*
- `Matrix & operator-= (const T_ &x)`  
*Operator -=.*

### 7.93.1 Detailed Description

**template<class T\_>class OFELI::SkSMatrix< T\_ >**

To handle symmetric matrices in skyline storage format.

This template class allows storing and manipulating a symmetric matrix in skyline storage format.

The matrix entries are stored column by column as in the following example:

```

/ \
| a0 a1 0 0 a7 |
| a2 a3 0 a8 |
| ... a4 a5 a9 |
| a6 a10 |
| a11 |
\ /

```

Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.93.2 Constructor & Destructor Documentation

**SkSMatrix ( )**

Default constructor.

Initializes a zero-dimension matrix

**SkSMatrix ( size\_t size, int is\_diagonal = false )**

Constructor that initializes a dense symmetric matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|                 |                          |                                                                     |
|-----------------|--------------------------|---------------------------------------------------------------------|
| <code>in</code> | <code>size</code>        | Number of matrix rows (and columns).                                |
| <code>in</code> | <code>is_diagonal</code> | Boolean to select if the matrix is diagonal or not [Default: false] |

**SkSMatrix ( Mesh & mesh, size\_t dof = 0, int is\_diagonal = false )**

Constructor using mesh to initialize skyline structure of matrix.

Parameters

|    |                    |                                                                                                                                                                                                                                             |
|----|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh</i>        | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| in | <i>dof</i>         | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |
| in | <i>is_diagonal</i> | Boolean argument to say is the matrix is actually a diagonal matrix or not.                                                                                                                                                                 |

### SkSMatrix ( const Vect< size\_t > & ColHt )

Constructor that initializes skyline structure of matrix using vector of column height.

Parameters

|    |              |                                                                     |
|----|--------------|---------------------------------------------------------------------|
| in | <i>ColHt</i> | <a href="#">Vect</a> instance that contains rows lengths of matrix. |
|----|--------------|---------------------------------------------------------------------|

### SkSMatrix ( const Vect< size\_t > & I, const Vect< size\_t > & J, int opt = 1 )

Constructor for a square matrix using non zero row and column indices.

Parameters

|    |            |                                                                                                                                                                                                       |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>I</i>   | Vector containing row indices                                                                                                                                                                         |
| in | <i>J</i>   | Vector containing column indices                                                                                                                                                                      |
| in | <i>opt</i> | Flag indicating if vectors I and J are cleaned and ordered (opt=1) or not (opt=0).<br>In the latter case, these vectors can contain the same contents more than once and are not necessarily ordered. |

### SkSMatrix ( const Vect< size\_t > & I, const Vect< size\_t > & J, const Vect< T\_ > & a, int opt = 1 )

Constructor for a square matrix using non zero row and column indices.

Parameters

|    |            |                                                                                                                                                                                                      |
|----|------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>I</i>   | Vector containing row indices                                                                                                                                                                        |
| in | <i>J</i>   | Vector containing column indices                                                                                                                                                                     |
| in | <i>a</i>   | Vector containing matrix entries in the same order than the one given by I and J                                                                                                                     |
| in | <i>opt</i> | Flag indicating if vectors I and J are cleaned and ordered (opt=1) or not (opt=0).<br>In the latter case, these vectors can contain the same contents more than once and are not necessarily ordered |

## 7.93.3 Member Function Documentation

### void setMesh ( Mesh & mesh, size\_t dof = 0 )

Determine mesh graph and initialize matrix.

This member function is called by constructor with the same arguments

Parameters

|    |             |                                                                                                                                                                                                                                             |
|----|-------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>mesh</i> | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| in | <i>dof</i>  | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |

**void setSkyline ( Mesh & *mesh* )**

Determine matrix structure.

This member function calculates matrix structure using [Mesh](#) instance *mesh*.

**void set ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Assign a value to an entry of the matrix.

Parameters

|    |            |                                             |
|----|------------|---------------------------------------------|
| in | <i>i</i>   | Row index                                   |
| in | <i>j</i>   | Column index                                |
| in | <i>val</i> | Value to assign to a( <i>i</i> , <i>j</i> ) |

Implements [Matrix< T\\_ >](#).

**void Axy ( T\_ *a*, const SkSMatrix< T\_ > & *m* )**

Add to matrix the product of a matrix by a scalar.

Parameters

|    |          |                                                                                 |
|----|----------|---------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                           |
| in | <i>m</i> | Matrix by which <i>a</i> is multiplied. The result is added to current instance |

**void Axy ( T\_ *a*, const Matrix< T\_ > \* *m* )** [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |          |                                                                                            |
|----|----------|--------------------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                                      |
| in | <i>m</i> | Pointer to Matrix by which <i>a</i> is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *x* and add to *y*.

Parameters

|        |          |                                                                      |
|--------|----------|----------------------------------------------------------------------|
| in     | <i>x</i> | Vector to multiply by matrix                                         |
| in,out | <i>y</i> | Vector to add to the result. <i>y</i> contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( T\_ *a*, const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *a*\**x* and add to *y*.



Parameters

|        |     |                                                               |
|--------|-----|---------------------------------------------------------------|
| in     | $a$ | Constant to multiply by matrix                                |
| in     | $x$ | Vector to multiply by matrix                                  |
| in,out | $y$ | Vector to add to the result. y contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void Mult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply matrix by vector x and save in y

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $x$ | Vector to multiply by matrix               |
| out | $y$ | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void TMult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply transpose of matrix by vector x and save in y.

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $x$ | Vector to multiply by matrix               |
| out | $y$ | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void add ( size\_t i, size\_t j, const T\_ & val )** [virtual]

Add a constant to an entry of the matrix.

Parameters

|    |       |                                  |
|----|-------|----------------------------------|
| in | $i$   | Row index                        |
| in | $j$   | Column index                     |
| in | $val$ | Constant value to add to a(i, j) |

Implements [Matrix< T\\_ >](#).

**size\_t getColHeight ( size\_t i ) const**

Return column height.

Column height at entry i is returned.

**T\_ & operator() ( size\_t i, size\_t j )** [virtual]

Operator () (Non constant version).

Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**T\_ operator() ( size\_t i, size\_t j ) const** [virtual]

Operator () (Constant version).

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**SkSMatrix< T\_ > & operator= ( const SkSMatrix< T\_ > & m )**

Operator =.

Copy matrix *m* to current matrix instance.

**SkSMatrix< T\_ > & operator= ( const T\_ & x )**

Operator =.

define the matrix as a diagonal one with all diagonal entries equal to *x*.

**SkSMatrix< T\_ > & operator+= ( const SkSMatrix< T\_ > & m )**

Operator +=.

Add matrix *m* to current matrix instance.

**SkSMatrix< T\_ > & operator\*= ( const T\_ & x )**

Operator \*.

Premultiply matrix entries by constant value *x*.

**int setLDLt ( )**

Factorize matrix (LDLt (Crout) factorization).

Returns

- 0 if factorization was normally performed
- *n* if the *n*-th pivot is null

**int solveLDLt ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve a linear system using the LDLt (Crout) factorization.

This function solves a linear system. The LDLt factorization is performed if this was not already done using the function setLU.

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null

Solution is performed only if factorization has previously been invoked.

**int solve ( Vect< T\_ > & b )** [virtual]

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LDLt decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLU. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLDLt realizes the factorization step only.

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve linear system.

The linear system having the current instance as a matrix is solved by using the LDLt decomposition. Solution is thus realized after a factorization step and a forward/backward substitution step. The factorization step is realized only if this was not already done.

Note that this function modifies the matrix contents if a factorization is performed. Naturally, if the matrix has been modified after using this function, the user has to refactorize it using the function setLDLt. This is because the class has no non-expensive way to detect if the matrix has been modified. The function setLDLt realizes the factorization step only.

Parameters

|     |          |                                                              |
|-----|----------|--------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side. |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution         |

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

**T\_\* get ( ) const**

Return C-Array.

Skyline of matrix is stored row by row.

**void setDiagonal ( Mesh & mesh )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t k ) const** [inherited]

Return *k*-th diagonal entry of matrix.

First entry is given by [getDiag\(1\)](#).

**void Assembly ( const Element & *el*, T\_ \* *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_ \* *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( int dof, int code, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                           |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                        |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & b, int flag = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                              |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that conatins imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |          |                                                                                             |
|--------|----------|---------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|--------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- n if the n-th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator () with one argument (Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |          |             |
|----|----------|-------------|
| in | <i>i</i> | entry index |
|----|----------|-------------|

**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|                 |                |             |
|-----------------|----------------|-------------|
| <code>in</code> | <code>i</code> | entry index |
|-----------------|----------------|-------------|

**`T_& operator[] ( size_t k )`** [inherited]

Operator [] (Non constant version).

Returns k-th stored element in matrix Index k starts at 0.

**`T_ operator[] ( size_t k ) const`** [inherited]

Operator [] (Constant version).

Returns k-th stored element in matrix Index k starts at 0.

**`Matrix& operator+=( const Matrix< T_ > & m )`** [inherited]

Operator +=.

Add matrix m to current matrix instance.

**`Matrix& operator+=( const T_ & x )`** [inherited]

Operator +=.

Add constant value x to all matrix entries.

**`Matrix& operator-=( const Matrix< T_ > & m )`** [inherited]

Operator -=.

Subtract matrix m from current matrix instance.

**`Matrix& operator-=( const T_ & x )`** [inherited]

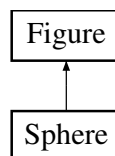
Operator -=.

Subtract constant value x from all matrix entries.

## 7.94 Sphere Class Reference

To store and treat a sphere.

Inheritance diagram for Sphere:



### Public Member Functions

- [Sphere](#) ()  
*Default constructor.*
- [Sphere](#) (const [Point](#)< [real\\_t](#) > &c, [real\\_t](#) r, int code=1)  
*Constructor.*
- void [setRadius](#) ([real\\_t](#) r)

- Assign radius of sphere.*
- `real_t getRadius () const`
- Return radius of sphere.*
- `void setCenter (const Point< real_t > &c)`
- Assign coordinates of center of sphere.*
- `Point< real_t > getCenter () const`
- Return coordinates of center of sphere.*
- `real_t getSignedDistance (const Point< real_t > &p) const`
- Return signed distance of a given point from the current sphere.*
- `Sphere & operator+= (Point< real_t > a)`
- Operator +=.*
- `Sphere & operator+= (real_t a)`
- Operator \*+=.*
- `void setCode (int code)`
- Choose a code for the domain defined by the figure.*
- `void getSIGNEDDistance (const Grid &g, Vect< real_t > &d) const`
- Calculate signed distance to current figure with respect to grid points.*
- `real_t dLine (const Point< real_t > &p, const Point< real_t > &a, const Point< real_t > &b) const`
- Compute signed distance from a line.*

### 7.94.1 Detailed Description

To store and treat a sphere.

### 7.94.2 Constructor & Destructor Documentation

**Sphere ( const Point< real\_t > & c, real\_t r, int code = 1 )**

Constructor.

Parameters

|    |             |                                                     |
|----|-------------|-----------------------------------------------------|
| in | <i>c</i>    | Coordinates of center of sphere                     |
| in | <i>r</i>    | Radius                                              |
| in | <i>code</i> | Code to assign to the generated sphere [Default: 1] |

### 7.94.3 Member Function Documentation

**real\_t getSIGNEDDistance ( const Point< real\_t > & p ) const** [virtual]

Return signed distance of a given point from the current sphere.

The computed distance is negative if p lies in the ball, positive if it is outside, and 0 on the sphere

Parameters

|    |          |                        |
|----|----------|------------------------|
| in | <i>p</i> | Point<double> instance |
|----|----------|------------------------|

Reimplemented from [Figure](#).

**Sphere& operator+= ( Point< real\_t > a )**

Operator +=.

Translate sphere by a vector a



**Sphere& operator+= ( real\_t a )**

Operator \*+=.

Scale sphere by a factor a

**void getSignedDistance ( const Grid &g, Vect< real\_t > &d ) const** [inherited]

Calculate signed distance to current figure with respect to grid points.

Parameters

|    |          |                                                                                                             |
|----|----------|-------------------------------------------------------------------------------------------------------------|
| in | <i>g</i> | <a href="#">Grid</a> instance                                                                               |
| in | <i>d</i> | <a href="#">Vect</a> instance containing calculated distance from each grid index to <a href="#">Figure</a> |

Remarks

Vector d doesn't need to be sized before invoking this function

**real\_t dLine ( const Point< real\_t > &p, const Point< real\_t > &a, const Point< real\_t > &b ) const** [inherited]

Compute signed distance from a line.

Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>p</i> | <a href="#">Point</a> for which distance is computed |
| in | <i>a</i> | First vertex of line                                 |
| in | <i>b</i> | Second vertex of line                                |

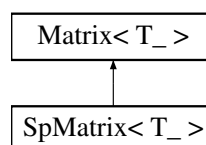
Returns

Signed distance

## 7.95 SpMatrix< T\_ > Class Template Reference

To handle matrices in sparse storage format.

Inheritance diagram for SpMatrix< T\_ >:



### Public Member Functions

- [SpMatrix](#) ()  
*Default constructor.*
- [SpMatrix](#) (size\_t nr, size\_t nc)  
*Constructor that initializes current instance as a dense matrix.*
- [SpMatrix](#) (size\_t size, int is\_diagonal=false)  
*Constructor that initializes current instance as a dense matrix.*
- [SpMatrix](#) ([Mesh](#) &mesh, size\_t dof=0, int is\_diagonal=false)

- Constructor using a [Mesh](#) instance.*
- [SpMatrix](#) (size\_t nr, size\_t nc, const vector< size\_t > &row\_ptr, const vector< size\_t > &col\_ind, const vector< T\_ > &a)
- Constructor for a rectangle matrix.*
- [SpMatrix](#) (const [SpMatrix](#) &m)
- Copy constructor.*
- [~SpMatrix](#) (void)
- Destructor.*
- void [Dense](#) ()
- Define matrix as a dense one.*
- void [Identity](#) ()
- Define matrix as identity matrix.*
- void [Diagonal](#) ()
- Define matrix as a diagonal one.*
- void [Diagonal](#) (const T\_ &a)
- Define matrix as a diagonal one with diagonal entries equal to a*
- void [Laplace1D](#) (size\_t n, real\_t h)
- Sets the matrix as the one for the Laplace equation in 1-D.*
- void [Laplace2D](#) (size\_t nx, size\_t ny)
- Sets the matrix as the one for the Laplace equation in 2-D.*
- void [setMesh](#) ([Mesh](#) &mesh, size\_t dof=0)
- Determine mesh graph and initialize matrix.*
- void [setOneDOF](#) ()
- Activate 1-DOF per node option.*
- void [setSides](#) ()
- Activate Sides option.*
- void [setDiag](#) ()
- Store diagonal entries in a separate internal vector.*
- void [DiagPrescribe](#) ([Mesh](#) &mesh, [Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u)
- Impose by a diagonal method an essential boundary condition.*
- void [DiagPrescribe](#) ([Vect](#)< T\_ > &b, const [Vect](#)< T\_ > &u)
- Impose by a diagonal method an essential boundary condition using the [Mesh](#) instance provided by the constructor.*
- void [setSize](#) (size\_t size)
- Set size of matrix (case where it's a square matrix).*
- void [setSize](#) (size\_t nr, size\_t nc)
- Set size (number of rows) of matrix.*
- void [setGraph](#) (const vector< RC > &I, int opt=1)
- Set graph of matrix by giving a vector of its nonzero entries.*
- [Vect](#)< T\_ > [getRow](#) (size\_t i) const
- Get i-th row vector.*
- [Vect](#)< T\_ > [getColumn](#) (size\_t j) const
- Get j-th column vector.*
- T\_ & [operator\(\)](#) (size\_t i, size\_t j)
- Operator () (Non constant version)*
- T\_ [operator\(\)](#) (size\_t i, size\_t j) const
- Operator () (Constant version)*

- `const T_ operator() (size_t i) const`  
*Operator () with one argument (Constant version)*
- `const T_ operator[] (size_t i) const`  
*Operator [] (Constant version).*
- `Vect< T_ > operator* (const Vect< T_ > &x) const`  
*Operator \* to multiply matrix by a vector.*
- `SpMatrix< T_ > & operator*= (const T_ &a)`  
*Operator \*= to premultiply matrix by a constant.*
- `void getMesh (Mesh &mesh)`  
*Get mesh instance whose reference will be stored in current instance of SpMatrix.*
- `void Mult (const Vect< T_ > &v, Vect< T_ > &w) const`  
*Multiply matrix by vector and save in another one.*
- `void MultAdd (const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply matrix by vector x and add to y.*
- `void MultAdd (T_ a, const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply matrix by vector a\*x and add to y.*
- `void TMult (const Vect< T_ > &x, Vect< T_ > &y) const`  
*Multiply transpose of matrix by vector x and save in y.*
- `void Axy (T_ a, const SpMatrix< T_ > &m)`  
*Add to matrix the product of a matrix by a scalar.*
- `void Axy (T_ a, const Matrix< T_ > *m)`  
*Add to matrix the product of a matrix by a scalar.*
- `void set (size_t i, size_t j, const T_ &val)`  
*Assign a value to an entry of the matrix.*
- `void add (size_t i, size_t j, const T_ &val)`  
*Add a value to an entry of the matrix.*
- `void operator= (const T_ &x)`  
*Operator =.*
- `size_t getColInd (size_t i) const`  
*Return storage information.*
- `size_t getRowPtr (size_t i) const`  
*Return Row pointer at position i.*
- `int solve (Vect< T_ > &b)`  
*Solve the linear system of equations.*
- `int solve (const Vect< T_ > &b, Vect< T_ > &x)`  
*Solve the linear system of equations.*
- `void setSolver (Iteration solver=CG_SOLVER, Preconditioner prec=DIAG_PREC, int max_it=1000, real_t toler=1.e-8)`  
*Choose solver and preconditioner for an iterative procedure.*
- `void clear ()`  
*brief Set all matrix entries to zero*
- `T_ * get () const`  
*Return C-Array.*
- `T_ get (size_t i, size_t j) const`  
*Return entry (i, j) of matrix if this one is stored, 0 otherwise.*
- `SpMat & getEigenMatrix ()`  
*Return reference to the matrix instance in Eigen library.*

- `size_t getNbRows () const`  
*Return number of rows.*
- `size_t getNbColumns () const`  
*Return number of columns.*
- `void setPenal (real_t p)`  
*Set Penalty Parameter (For boundary condition prescription).*
- `void setDiagonal ()`  
*Set the matrix as diagonal.*
- `void setDiagonal (Mesh &mesh)`  
*Initialize matrix storage in the case where only diagonal terms are stored.*
- `T_ getDiag (size_t k) const`  
*Return k-th diagonal entry of matrix.*
- `size_t size () const`  
*Return matrix dimension (Number of rows and columns).*
- `void Assembly (const Element &el, T_ *a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Element &el, const DMatrix< T_ > &a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Side &sd, T_ *a)`  
*Assembly of side matrix into global matrix.*
- `void Assembly (const Side &sd, const DMatrix< T_ > &a)`  
*Assembly of side matrix into global matrix.*
- `void Prescribe (Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.*
- `void Prescribe (int dof, int code, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- `void Prescribe (Vect< T_ > &b, int flag=0)`  
*Impose by a penalty method a homogeneous (=0) essential boundary condition.*
- `void Prescribe (size_t dof, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- `void PrescribeSide ()`  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- `virtual int Factor ()=0`  
*Factorize matrix. Available only if the storage class enables it.*
- `int FactorAndSolve (Vect< T_ > &b)`  
*Factorize matrix and solve the linear system.*
- `int FactorAndSolve (const Vect< T_ > &b, Vect< T_ > &x)`  
*Factorize matrix and solve the linear system.*
- `size_t getLength () const`  
*Return number of stored terms in matrix.*
- `int isDiagonal () const`  
*Say if matrix is diagonal or not.*
- `int isFactorized () const`  
*Say if matrix is factorized or not.*
- `T_ & operator() (size_t i)`  
*Operator () with one argument (Non Constant version).*

- `T_ & operator[] (size_t k)`  
*Operator [] (Non constant version).*
- `Matrix & operator+= (const Matrix< T_ > &m)`  
*Operator +=.*
- `Matrix & operator+= (const T_ &x)`  
*Operator +=.*
- `Matrix & operator-= (const Matrix< T_ > &m)`  
*Operator -=.*
- `Matrix & operator-= (const T_ &x)`  
*Operator -=.*

## Friends

- `template<class TT_ >`  
`ostream & operator<< (ostream &s, const SpMatrix< TT_ > &A)`

### 7.95.1 Detailed Description

**template<class T\_>class OFELI::SpMatrix< T\_ >**

To handle matrices in sparse storage format.

This template class enables storing and manipulating a sparse matrix, i.e. only nonzero terms are stored. Internally, the matrix is stored as a vector instance and uses for the definition of its graph a `Vect<size_t>` instance `row_ptr` and a `Vect<size_t>` instance `col_ind` that contains respectively addresses of first element of each row and column indices.

To illustrate this, consider the matrix

```

1 2 0
3 4 0
0 5 0

```

Such a matrix is stored in the `vector<real_t>` instance `{1,2,3,4,5}`. The vectors `row_ptr` and `col_ind` are respectively: `{0,2,4,5}`, `{1,2,1,2,2}`

When the library `eigen` is used in conjunction with `OFELI`, the class uses the sparse matrix class of `eigen` and enables then access to specific solvers (see class `LinearSolver`)

Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.95.2 Constructor & Destructor Documentation

**SpMatrix ( )**

Default constructor.

Initialize a zero-dimension matrix

**SpMatrix ( size\_t nr, size\_t nc )**

Constructor that initializes current instance as a dense matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|                 |                 |                           |
|-----------------|-----------------|---------------------------|
| <code>in</code> | <code>nr</code> | Number of matrix rows.    |
| <code>in</code> | <code>nc</code> | Number of matrix columns. |

**SpMatrix ( `size_t size`, `int is_diagonal = false` )**

Constructor that initializes current instance as a dense matrix.

Normally, for a dense matrix this is not the right class.

Parameters

|                 |                          |                                                                             |
|-----------------|--------------------------|-----------------------------------------------------------------------------|
| <code>in</code> | <code>size</code>        | Number of matrix rows (and columns).                                        |
| <code>in</code> | <code>is_diagonal</code> | Boolean argument to say is the matrix is actually a diagonal matrix or not. |

**SpMatrix ( `Mesh & mesh`, `size_t dof = 0`, `int is_diagonal = false` )**

Constructor using a [Mesh](#) instance.

Parameters

|                 |                          |                                                                                                                                                                                                                                             |
|-----------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>mesh</code>        | <a href="#">Mesh</a> instance from which matrix graph is extracted.                                                                                                                                                                         |
| <code>in</code> | <code>dof</code>         | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |
| <code>in</code> | <code>is_diagonal</code> | Boolean argument to say is the matrix is actually a diagonal matrix or not.                                                                                                                                                                 |

**SpMatrix ( `size_t nr`, `size_t nc`, `const vector< size_t > & row_ptr`, `const vector< size_t > & col_ind`, `const vector< T_ > & a` )**

Constructor for a rectangle matrix.

Parameters

|                 |                      |                                                                     |
|-----------------|----------------------|---------------------------------------------------------------------|
| <code>in</code> | <code>nr</code>      | Number of rows                                                      |
| <code>in</code> | <code>nc</code>      | Number of columns                                                   |
| <code>in</code> | <code>row_ptr</code> | Vector of row pointers (See the above description of this class).   |
| <code>in</code> | <code>col_ind</code> | Vector of column indices (See the above description of this class). |
| <code>in</code> | <code>a</code>       | vector instance containing matrix entries stored columnwise         |

### 7.95.3 Member Function Documentation

**void Laplace1D ( `size_t n`, `real_t h` )**

Sets the matrix as the one for the Laplace equation in 1-D.

The matrix is initialized as the one resulting from  $P_1$  finite element discretization of the classical elliptic operator  $-u'' = f$  with homogeneous Dirichlet boundary conditions

Remarks

This function is available for real valued matrices only.

Parameters

|    |     |                                 |
|----|-----|---------------------------------|
| in | $n$ | Size of matrix (Number of rows) |
| in | $h$ | Mesh size (assumed constant)    |

**void Laplace2D ( size.t nx, size.t ny )**

Sets the matrix as the one for the Laplace equation in 2-D.

The matrix is initialized as the one resulting from  $P_1$  finite element discretization of the classical elliptic operator  $-\Delta u = f$  with homogeneous Dirichlet boundary conditions

Remarks

This function is available for real valued matrices only.

Parameters

|    |      |                                       |
|----|------|---------------------------------------|
| in | $nx$ | Number of unknowns in the x-direction |
| in | $ny$ | Number of unknowns in the y-direction |

Remarks

The number of rows is equal to  $nx*ny$

**void setMesh ( Mesh & mesh, size.t dof = 0 )**

Determine mesh graph and initialize matrix.

This member function is called by constructor with the same arguments

Parameters

|    |        |                                                                                                                                                                                                                                             |
|----|--------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | $mesh$ | <a href="#">Mesh</a> instance for which matrix graph is determined.                                                                                                                                                                         |
| in | $dof$  | Option parameter, with default value 0.<br>dof=1 means that only one degree of freedom for each node (or element or side) is taken to determine matrix structure. The value dof=0 means that matrix structure is determined using all DOFs. |

**void DiagPrescribe ( Mesh & mesh, Vect< T\_ > & b, const Vect< T\_ > & u )**

Impose by a diagonal method an essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |        |                                                                                                  |
|--------|--------|--------------------------------------------------------------------------------------------------|
| in     | $mesh$ | <a href="#">Mesh</a> instance from which information is extracted.                               |
| in,out | $b$    | <a href="#">Vect</a> instance that contains right-hand side.                                     |
| in     | $u$    | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed. |

**void DiagPrescribe ( Vect< T\_ > & b, const Vect< T\_ > & u )**

Impose by a diagonal method an essential boundary condition using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |          |                                                                                                  |
|--------|----------|--------------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side.                                     |
| in     | <i>u</i> | <a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed. |

**void setSize ( size\_t size )**

Set size of matrix (case where it's a square matrix).

Parameters

|    |             |                             |
|----|-------------|-----------------------------|
| in | <i>size</i> | Number of rows and columns. |
|----|-------------|-----------------------------|

**void setSize ( size\_t nr, size\_t nc )**

Set size (number of rows) of matrix.

Parameters

|    |           |                   |
|----|-----------|-------------------|
| in | <i>nr</i> | Number of rows    |
| in | <i>nc</i> | Number of columns |

**void setGraph ( const vector< RC > & I, int opt = 1 )**

Set graph of matrix by giving a vector of its nonzero entries.

Parameters

|    |            |                                                                                                                                                                                               |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>I</i>   | Vector containing pairs of row and column indices                                                                                                                                             |
| in | <i>opt</i> | Flag indicating if vector I is cleaned and ordered (opt=1: default) or not (opt=0). In the latter case, this vector can have the same contents more than once and are not necessarily ordered |

**T\_& operator() ( size\_t i, size\_t j )** [virtual]

Operator () (Non constant version)

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**T\_ operator() ( size\_t i, size\_t j ) const** [virtual]

Operator () (Constant version)



Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>i</i> | Row index    |
| in | <i>j</i> | Column index |

Implements [Matrix< T\\_ >](#).

**const T\_ operator() ( size\_t i ) const**

Operator () with one argument (Constant version)

Returns *i*-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

**const T\_ operator[] ( size\_t i ) const**

Operator [] (Constant version).

Returns *i*-th position in the array storing matrix entries. The first entry is at location 0. Entries are stored row by row.

**Vect<T\_> operator\* ( const Vect< T\_ > & x ) const**

Operator \* to multiply matrix by a vector.

Parameters

|    |          |                                              |
|----|----------|----------------------------------------------|
| in | <i>x</i> | <a href="#">Vect</a> instance to multiply by |
|----|----------|----------------------------------------------|

Returns

Vector product of matrix by *x*

**SpMatrix<T\_>& operator\*= ( const T\_ & a )**

Operator \*= to premultiply matrix by a constant.

Parameters

|    |          |                                |
|----|----------|--------------------------------|
| in | <i>a</i> | Constant to multiply matrix by |
|----|----------|--------------------------------|

Returns

Resulting matrix

**void Mult ( const Vect< T\_ > & v, Vect< T\_ > & w ) const [virtual]**

Multiply matrix by vector and save in another one.

Parameters

|     |          |                                            |
|-----|----------|--------------------------------------------|
| in  | <i>v</i> | Vector to multiply by matrix               |
| out | <i>w</i> | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( const Vect< T\_ > & x, Vect< T\_ > & y ) const [virtual]**

Multiply matrix by vector *x* and add to *y*.

Parameters

|     |     |                                                                 |
|-----|-----|-----------------------------------------------------------------|
| in  | $x$ | Vector to multiply by matrix                                    |
| out | $y$ | Vector to add to the result. $y$ contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void MultAdd ( T\_  $a$ , const Vect< T\_ > &  $x$ , Vect< T\_ > &  $y$  ) const** [virtual]

Multiply matrix by vector  $a*x$  and add to  $y$ .

Parameters

|     |     |                                                                 |
|-----|-----|-----------------------------------------------------------------|
| in  | $a$ | Constant to multiply by matrix                                  |
| in  | $x$ | Vector to multiply by matrix                                    |
| out | $y$ | Vector to add to the result. $y$ contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void TMult ( const Vect< T\_ > &  $x$ , Vect< T\_ > &  $y$  ) const** [virtual]

Multiply transpose of matrix by vector  $x$  and save in  $y$ .

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $x$ | Vector to multiply by matrix               |
| out | $y$ | Vector that contains on output the result. |

Implements [Matrix< T\\_ >](#).

**void Axy ( T\_  $a$ , const SpMatrix< T\_ > &  $m$  )**

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                            |
|----|-----|----------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                      |
| in | $m$ | Matrix by which $a$ is multiplied. The result is added to current instance |

**void Axy ( T\_  $a$ , const Matrix< T\_ > \*  $m$  )** [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

|    |     |                                                                                                       |
|----|-----|-------------------------------------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                                                 |
| in | $m$ | Pointer to <a href="#">Matrix</a> by which $a$ is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**void set ( size\_t  $i$ , size\_t  $j$ , const T\_ &  $val$  )** [virtual]

Assign a value to an entry of the matrix.

Parameters

|    |       |                              |
|----|-------|------------------------------|
| in | $i$   | Row index                    |
| in | $j$   | Column index                 |
| in | $val$ | Value to assign to $a(i, j)$ |

Implements [Matrix< T\\_ >](#).

**void add ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Add a value to an entry of the matrix.

Parameters

|                 |                  |                                               |
|-----------------|------------------|-----------------------------------------------|
| <code>in</code> | <code>i</code>   | Row index                                     |
| <code>in</code> | <code>j</code>   | Column index                                  |
| <code>in</code> | <code>val</code> | Constant value to add to <code>a(i, j)</code> |

Implements [Matrix< T\\_ >](#).

**void operator= ( const T\_ & x )**

Operator =.

Assign constant value `x` to all matrix entries.

**size\_t getColInd ( size\_t i ) const** [virtual]

Return storage information.

Returns

Column index of the `i`-th stored element in matrix

Reimplemented from [Matrix< T\\_ >](#).

**int solve ( Vect< T\_ > & b )** [virtual]

Solve the linear system of equations.

The default parameters are:

- CG\_SOLVER for solver
- DIAG\_PREC for preconditioner
- Max. Number of iterations is 1000
- Tolerance is 1.e-8

To change these values, call function `setSolver` before this function

Parameters

|                      |                |                                                                      |
|----------------------|----------------|----------------------------------------------------------------------|
| <code>in, out</code> | <code>b</code> | Vector that contains right-hand side on input and solution on output |
|----------------------|----------------|----------------------------------------------------------------------|

Returns

Number of actual performed iterations

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve the linear system of equations.

The default parameters are:

- CG\_SOLVER for solver
- DIAG\_PREC for preconditioner
- Max. Number of iterations is 1000
- Tolerance is 1.e-8

To change these values, call function `setSolver` before this function

Parameters

|     |     |                                            |
|-----|-----|--------------------------------------------|
| in  | $b$ | Vector that contains right-hand side       |
| out | $x$ | Vector that contains the obtained solution |

Returns

Number of actual performed iterations

**void setSolver ( Iteration *solver* = CG\_SOLVER, Preconditioner *prec* = DIAG\_PREC, int *max\_it* = 1000, real\_t *toler* = 1.e-8 )**

Choose solver and preconditioner for an iterative procedure.

Parameters

|    |               |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |
|----|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>solver</i> | Option to choose iterative solver in an enumerated variable <ul style="list-style-type: none"> <li>• CG_SOLVER: Conjugate Gradient [default]</li> <li>• CGS_SOLVER: Squared conjugate gradient</li> <li>• BICG_SOLVER: Biconjugate gradient</li> <li>• BICG_STAB_SOLVER: Biconjugate gradient stabilized</li> <li>• GMRES_SOLVER: Generalized Minimal Residual</li> </ul> Default value is CG_SOLVER                                                                                       |
| in | <i>prec</i>   | Option to choose preconditioner in an enumerated variable <ul style="list-style-type: none"> <li>• IDENT_PREC: Identity preconditioner (no preconditioning)</li> <li>• DIAG_PREC: Diagonal preconditioner [default]</li> <li>• SSOR_PREC: SSOR (Symmetric Successive Over Relaxation) preconditioner</li> <li>• DILU_PREC: ILU (Diagonal Incomplete factorization) preconditioner</li> <li>• ILU_PREC: ILU (Incomplete factorization) preconditioner</li> </ul> Default value is DIAG_PREC |
| in | <i>max_it</i> | Maximum number of allowed iterations. Default value is 1000.                                                                                                                                                                                                                                                                                                                                                                                                                               |
| in | <i>toler</i>  | Tolerance for convergence. Default value is 1.e-8                                                                                                                                                                                                                                                                                                                                                                                                                                          |

**T\_\* get ( ) const**

Return C-Array.

Non zero terms of matrix is stored row by row.

**T\_ get ( size\_t *i*, size\_t *j* ) const** [virtual]

Return entry (*i*, *j*) of matrix if this one is stored, 0 otherwise.

Parameters

|    |          |                                |
|----|----------|--------------------------------|
| in | <i>i</i> | Row index (Starting from 1)    |
| in | <i>j</i> | Column index (Starting from 1) |

Implements [Matrix< T\\_ >](#).

**void setDiagonal ( Mesh & *mesh* )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t *k* ) const** [inherited]

Return *k*-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & *el*, T\_\* *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_\* *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( int *dof*, int *code*, Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                              |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                           |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                                |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified<br>(dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & *b*, int *flag* = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                                 |
|--------|-------------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                    |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This function is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function setPenal.

Parameters

|        |      |                                                                                                                                                 |
|--------|------|-------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | dof  | Label of the concerned degree of freedom (DOF).                                                                                                 |
| in,out | b    | Vect instance that contains right-hand side.                                                                                                    |
| in     | u    | Vect instance that contains imposed values at DOFs where they are to be imposed.                                                                |
| in     | flag | Parameter to determine whether only the right-hand side is to be modified (dof>0)<br>or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function setPenal(..).

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |   |                                                                             |
|--------|---|-----------------------------------------------------------------------------|
| in,out | b | Vect instance that contains right-hand side on input and solution on output |
|--------|---|-----------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |   |                                             |
|-----|---|---------------------------------------------|
| in  | b | Vect instance that contains right-hand side |
| out | x | Vect instance that contains solution        |

Returns

- 0 if solution was normally performed
- n if the n-th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.



**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|          |          |             |
|----------|----------|-------------|
| <i>i</i> | <i>i</i> | entry index |
|----------|----------|-------------|

**T\_& operator[] ( size\_t k )** [inherited]

Operator [] (Non constant version).

Returns k-th stored element in matrix Index k starts at 0.

**Matrix& operator+=( const Matrix< T\_ > & m )** [inherited]

Operator +=.

Add matrix *m* to current matrix instance.

**Matrix& operator+=( const T\_ & x )** [inherited]

Operator +=.

Add constant value *x* to all matrix entries.

**Matrix& operator-=( const Matrix< T\_ > & m )** [inherited]

Operator -=.

Subtract matrix *m* from current matrix instance.

**Matrix& operator-=( const T\_ & x )** [inherited]

Operator -=.

Subtract constant value *x* from all matrix entries.

## 7.96 SteklovPoincare2DBE Class Reference

Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elements.

### Public Member Functions

- [SteklovPoincare2DBE](#) (bool ext=false)  
*Default Constructor.*
- [SteklovPoincare2DBE](#) (const [Mesh](#) &mesh, bool ext=false)  
*Constructor using mesh data.*
- [SteklovPoincare2DBE](#) (const [Mesh](#) &mesh, const [Vect](#)< [real\\_t](#) > &g, [Vect](#)< [real\\_t](#) > &b, bool ext=false)  
*Constructor that solves the Steklov Poincare problem.*
- [~SteklovPoincare2DBE](#) ()  
*Destructor.*
- void [setMesh](#) (const [Mesh](#) &mesh, bool ext=false)  
*set [Mesh](#) instance*

- void [Solve](#) ()  
*Build equation left and right-hand sides for  $P_0$  (piecewise constant) approximation.*
- int [Solve](#) ([Vect](#)< [real\\_t](#) > &b, const [Vect](#)< [real\\_t](#) > &g)  
*Build equation left and right-hand sides for  $P_0$  (piecewise constant) approximation.*

### 7.96.1 Detailed Description

Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elements.

[SteklovPoincare2DBE](#) solves the Steklov Poincare problem in 2-D: Given the trace of a harmonic function on the boundary of a given (inner or outer) domain, this class computes the normal derivative of the function. The normal is considered as oriented out of the bounded (inner) domain in both inner and outer configurations. The numerical approximation uses piecewise constant ( $P_0$ ) approximation on edges of the boundary. Solution is obtained from the GMRES iterative solver without preconditioning. The given data is the vector (instance of class [Vect](#)) of piecewise constant values of the harmonic function on the boundary and the returned solution is piecewise constant value of the normal derivative considered either as a [Vect](#) instance.

Note

Although the mesh of the inner domain is not necessary to solve the problem, this one must be provided in order to calculate the outward normal.

### 7.96.2 Constructor & Destructor Documentation

**[SteklovPoincare2DBE](#) ( [bool](#) *ext* = *false* )**

Default Constructor.

Parameters

|                    |            |                                                                                              |
|--------------------|------------|----------------------------------------------------------------------------------------------|
| <a href="#">in</a> | <i>ext</i> | Boolean variable to say if the domain is external (true) or internal (false: Default value). |
|--------------------|------------|----------------------------------------------------------------------------------------------|

**[SteklovPoincare2DBE](#) ( const [Mesh](#) & *mesh*, [bool](#) *ext* = *false* )**

Constructor using mesh data.

This constructor calls member function [setMesh](#).

Parameters

|                    |             |                                                                                              |
|--------------------|-------------|----------------------------------------------------------------------------------------------|
| <a href="#">in</a> | <i>mesh</i> | Reference to mesh instance.                                                                  |
| <a href="#">in</a> | <i>ext</i>  | Boolean variable to say if the domain is external (true) or internal (false: Default value). |

**[SteklovPoincare2DBE](#) ( const [Mesh](#) & *mesh*, const [Vect](#)< [real\\_t](#) > &g, [Vect](#)< [real\\_t](#) > &b, [bool](#) *ext* = *false* )**

Constructor that solves the Steklov Poincare problem.

This constructor calls member function [setMesh](#) and [Solve](#).

Parameters

|                    |             |                                                                                                    |
|--------------------|-------------|----------------------------------------------------------------------------------------------------|
| <a href="#">in</a> | <i>mesh</i> | Reference to mesh instance.                                                                        |
| <a href="#">in</a> | <i>g</i>    | <a href="#">Vect</a> instance that contains imposed solution on the boundary                       |
| <a href="#">in</a> | <i>b</i>    | <a href="#">Vect</a> instance that contains the left hand side in input and the solution in output |
| <a href="#">in</a> | <i>ext</i>  | Boolean variable to say if the domain is external (true) or internal (false: Default value).       |

### 7.96.3 Member Function Documentation

**void setMesh ( const Mesh & mesh, bool ext = false )**

set [Mesh](#) instance

Parameters

|    |      |                                                                                              |
|----|------|----------------------------------------------------------------------------------------------|
| in | mesh | <a href="#">Mesh</a> instance                                                                |
| in | ext  | Boolean variable to say if the domain is external (true) or internal (false: Default value). |

**void Solve ( )**

Build equation left and right-hand sides for  $P_0$  (piecewise constant) approximation.

This member function is to be used if the constructor using mesh, b and g has been used.

**int Solve ( Vect< real.t > & b, const Vect< real.t > & g )**

Build equation left and right-hand sides for  $P_0$  (piecewise constant) approximation.

This member function is to be used if the constructor using mesh has been used. It concerns cases where the imposed boundary condition is given by sides

Parameters

|    |   |                                                                             |
|----|---|-----------------------------------------------------------------------------|
| in | g | Vector that contains imposed solution on the boundary                       |
| in | b | Vector that contains the left hand side in input and the solution in output |

## 7.97 Tabulation Class Reference

To read and manipulate tabulated functions.

### Public Member Functions

- [Tabulation](#) ()  
*Default constructor.*
- [Tabulation](#) (string file)  
*Constructor using file name.*
- [~Tabulation](#) ()  
*Destructor.*
- void [setFile](#) (string file)  
*Set file name.*
- [real.t](#) [getValue](#) (string funct, [real.t](#) v)  
*Return the calculated value of the function.*
- [real.t](#) [getDerivative](#) (string funct, [real.t](#) v)  
*Return the derivative of the function at a given point.*
- [real.t](#) [getValue](#) (string funct, [real.t](#) v1, [real.t](#) v2)  
*Return the calculated value of the function.*
- [real.t](#) [getValue](#) (string funct, [real.t](#) v1, [real.t](#) v2, [real.t](#) v3)  
*Return the calculated value of the function.*

### 7.97.1 Detailed Description

To read and manipulate tabulated functions.

This class enables reading a tabulated function of one to three variables and calculating the value of the function using piecewise multilinear interpolation.

The file defining the function is an XML file where any function is introduced via the tag "Function".

### 7.97.2 Member Function Documentation

**void setFile ( string *file* )**

Set file name.

This function is to be used when the default constructor is invoked.

**real.t getValue ( string *funct*, real.t *v* )**

Return the calculated value of the function.

Case of a function of one variable

Parameters

|    |              |                                                               |
|----|--------------|---------------------------------------------------------------|
| in | <i>funct</i> | Name of the function to be evaluated, as read from input file |
| in | <i>v</i>     | Value of the variable                                         |

Returns

Computed value of the function

**real.t getDerivative ( string *funct*, real.t *v* )**

Return the derivative of the function at a given point.

Case of a function of one variable

Parameters

|    |              |                                                               |
|----|--------------|---------------------------------------------------------------|
| in | <i>funct</i> | Name of the function to be evaluated, as read from input file |
| in | <i>v</i>     | Value of the variable                                         |

Returns

Derivative value

**real.t getValue ( string *funct*, real.t *v1*, real.t *v2* )**

Return the calculated value of the function.

Case of a function of two variables

Parameters

|    |              |                                                               |
|----|--------------|---------------------------------------------------------------|
| in | <i>funct</i> | Name of the function to be evaluated, as read from input file |
| in | <i>v1</i>    | Value of the first variable                                   |
| in | <i>v2</i>    | Value of the second variable                                  |

Returns

Computed value of the function

**real.t** `getValue ( string funct, real.t v1, real.t v2, real.t v3 )`

Return the calculated value of the function.

Case of a function of three variables

## Parameters

|    |             |                                                            |
|----|-------------|------------------------------------------------------------|
| in | <i>func</i> | Name of the funct to be evaluated, as read from input file |
| in | <i>v1</i>   | Value of the first variable                                |
| in | <i>v2</i>   | Value of the second variable                               |
| in | <i>v3</i>   | Value of the third variable                                |

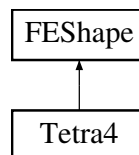
## Returns

Computed value of the function

## 7.98 Tetra4 Class Reference

Defines a three-dimensional 4-node tetrahedral finite element using  $P_1$  interpolation.

Inheritance diagram for Tetra4:



### Public Member Functions

- [Tetra4](#) ()  
*Default Constructor.*
- [Tetra4](#) (const [Element](#) \*el)  
*Constructor when data of [Element](#) el are given.*
- [~Tetra4](#) ()  
*Destructor.*
- void [set](#) (const [Element](#) \*el)  
*Choose element by giving its pointer.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node i at a given point s.*
- [Point](#)< [real\\_t](#) > [DSh](#) (size\_t i) const  
*Return x, y and z partial derivatives of shape function associated to node i.*
- [real\\_t](#) [getVolume](#) () const  
*Return volume of element.*
- [Point](#)< [real\\_t](#) > [getRefCoord](#) (const [Point](#)< [real\\_t](#) > &x) const  
*Return reference coordinates of a point x in element.*
- bool [isIn](#) (const [Point](#)< [real\\_t](#) > &x)  
*Check whether point x is in current tetrahedron or not.*
- [real\\_t](#) [getInterpolate](#) (const [Point](#)< [real\\_t](#) > &x, const [LocalVect](#)< [real\\_t](#), 4 > &v)  
*Return interpolated value at point of coordinate x*
- [Point](#)< [real\\_t](#) > [EdgeSh](#) (size\_t k, [Point](#)< [real\\_t](#) > s)  
*Return edge shape function.*
- [Point](#)< [real\\_t](#) > [CurlEdgeSh](#) (size\_t k)  
*Return curl of edge shape function.*
- [real\\_t](#) [getMaxEdgeLength](#) () const

- Return maximal edge length of tetrahedron.*
- `real_t getMinEdgeLength () const`
- Return minimal edge length of tetrahedron.*
- `real_t Sh (size_t i) const`
- Return shape function of node  $i$  at given point.*
- `real_t getDet () const`
- Return determinant of jacobian.*
- `Point< real_t > getCenter () const`
- Return coordinates of center of element.*
- `Point< real_t > getLocalPoint () const`
- Localize a point in the element.*
- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`
- Localize a point in the element.*

### 7.98.1 Detailed Description

Defines a three-dimensional 4-node tetrahedral finite element using  $P_1$  interpolation.  
The reference element is the right tetrahedron with four unit edges interpolation.

### 7.98.2 Member Function Documentation

**`real_t Sh ( size_t i, Point< real_t > s ) const`**

Calculate shape function of node  $i$  at a given point  $s$ .  
 $s$  is a point in the reference tetrahedron.

**`Point<real_t> DSh ( size_t i ) const`**

Return  $x$ ,  $y$  and  $z$  partial derivatives of shape function associated to node  $i$ .  
Note that these are constant in element.

**`Point<real_t> EdgeSh ( size_t k, Point< real_t > s )`**

Return edge shape function.  
Parameters

|                 |                |                                                                 |
|-----------------|----------------|-----------------------------------------------------------------|
| <code>in</code> | <code>k</code> | Local edge number for which the edge shape function is computed |
| <code>in</code> | <code>s</code> | Local coordinates in element                                    |

Remarks

`Element` edges are ordered as follows: `Edge k` has end vertices  $k$  and  $k+1$

**`Point<real_t> CurlEdgeSh ( size_t k )`**

Return curl of edge shape function.

Parameters

|                 |                |                                                                             |
|-----------------|----------------|-----------------------------------------------------------------------------|
| <code>in</code> | <code>k</code> | Local edge number for which the curl of the edge shape function is computed |
|-----------------|----------------|-----------------------------------------------------------------------------|

Remarks

[Element](#) edges are ordered as follows: [Edge](#) `k` has end vertices `k` and `k+1`

**`real_t getDet ( ) const`** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **`setLocal()`** must have been called before in order to calculate relevant quantities.

**`Point<real_t> getLocalPoint ( ) const`** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **`setLocal()`** must have been called before in order to calculate relevant quantities.

**`Point<real_t> getLocalPoint ( const Point< real_t > & s ) const`** [inherited]

Localize a point in the element.

Return actual coordinates where `s` are coordinates in the reference element.

## 7.99 Timer Class Reference

To handle elapsed time counting.

### Public Member Functions

- [Timer](#) ()  
*Default constructor.*
- [~Timer](#) ()  
*Destructor.*
- bool [Started](#) () const  
*Say if time counter has started.*
- void [Start](#) ()  
*Start (or resume) time counting.*
- void [Stop](#) ()  
*Stop time counting.*
- void [Clear](#) ()  
*Clear time value (Set to zero)*
- [real\\_t get](#) () const  
*Return elapsed time (in seconds)*
- [real\\_t getTime](#) () const  
*Return elapsed time (in seconds)*



### 7.99.1 Detailed Description

To handle elapsed time counting.

This class is to be used when testing program performances. A normal usage of the class is, once an instance is constructed, to use alternatively, Start, Stop and Resume. Elapsed time can be obtained once the member function Stop is called.

### 7.99.2 Member Function Documentation

**bool Started ( ) const**

Say if time counter has started.

Return true if time has started, false if not

**void Start ( )**

Start (or resume) time counting.

This member function is to be used to start or resume time counting

**void Stop ( )**

Stop time counting.

This function interrupts time counting. This one can be resumed by the function Start

**real\_t getTime ( ) const**

Return elapsed time (in seconds)

Identical to get

## 7.100 TimeStepping Class Reference

To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form  $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$ .

### Public Member Functions

- [TimeStepping \( \)](#)  
*Default constructor.*
- [TimeStepping \(TimeScheme s, real\\_t time\\_step=theTimeStep, real\\_t final\\_time=theFinalTime\)](#)  
*Constructor using time discretization data.*
- [~TimeStepping \( \)](#)  
*Destructor.*
- void [set \(TimeScheme s, real\\_t time\\_step=theTimeStep, real\\_t final\\_time=theFinalTime\)](#)  
*Define data of the differential equation or system.*
- void [setPDE \(AbsEqua< real\\_t > &eq\)](#)  
*Define partial differential equation to solve.*
- void [setRK4RHS \(Vect< real\\_t > &f\)](#)  
*Set intermediate right-hand side vector for the Runge-Kutta method.*
- void [setInitial \(Vect< real\\_t > &u\)](#)  
*Set initial condition for the system of differential equations.*
- void [setInitial \(Vect< real\\_t > &u, Vect< real\\_t > &v\)](#)  
*Set initial condition for a system of differential equations.*

- void `setInitialRHS` (`Vect< real_t > &f`)  
*Set initial RHS for a system of differential equations when the used scheme requires it.*
- void `setRHS` (`Vect< real_t > &b`)  
*Set right-hand side vector.*
- void `setBC` (`Vect< real_t > &u`)  
*Set vector containing boundary condition to enforce.*
- void `setNewmarkParameters` (`real_t` beta, `real_t` gamma)  
*Define parameters for the Newmark scheme.*
- void `setConstantMatrix` ()  
*Say that matrix problem is constant.*
- void `setNonConstantMatrix` ()  
*Say that matrix problem is variable.*
- void `setLinearSolver` (`Iteration` s=`DIRECT_SOLVER`, `Preconditioner` p=`DIAG_PREC`)  
*Set linear solver data.*
- void `setVerbose` (`int` v=0)  
*Set verbosity parameter:*
- `real_t` `runOneTimeStep` ()  
*Run one time step.*
- void `run` (`bool` opt=false)  
*Run the time stepping procedure.*
- void `Assembly` (`const Element` &el, `real_t` \*b, `real_t` \*A0, `real_t` \*A1, `real_t` \*A2=NULL)  
*Assemble element arrays into global matrix and right-hand side.*
- void `SAssembly` (`const Side` &sd, `real_t` \*b, `real_t` \*A=NULL)  
*Assemble side arrays into global matrix and right-hand side.*
- `LinearSolver< real_t > &getLSolver` ()  
*Return LinearSolver instance.*

### 7.100.1 Detailed Description

To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form  $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$ .

Features:

- The system may be first or second order (first and/or second order time derivatives)
- The following time integration schemes can be used:
  - For first order systems: The following schemes are implemented Forward Euler (value: `FORWARD_EULER`)  
Backward Euler (value: `BACKWARD_EULER`)  
Crank-Nicolson (value: `CRANK_NICOLSON`)  
Heun (value: `HEUN`)  
2nd Order Adams-Bashforth (value: `AB2`)  
4-th order Runge-Kutta (value: `RK4`)  
2nd order Backward Differentiation Formula (value: `BDF2`)
  - For second order systems: The following schemes are implemented Newmark (value: `NEWMARK`)

### 7.100.2 Constructor & Destructor Documentation

**TimeStepping** ( *TimeScheme* *s*, *real\_t* *time\_step* = *theTimeStep*, *real\_t* *final\_time* = *theFinalTime* )

Constructor using time discretization data.

Parameters

|    |                   |                                                                                                                                                                                            |
|----|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>s</i>          | Choice of the scheme: To be chosen in the enumerated variable <i>TimeScheme</i> (see the presentation of the class)                                                                        |
| in | <i>time_step</i>  | Value of the time step. This value will be modified if an adaptive method is used. The default value for this parameter is the value given by the global variable <code>theTimeStep</code> |
| in | <i>final_time</i> | Value of the final time (time starts at 0). The default value for this parameter is the value given by the global variable <code>theFinalTime</code>                                       |

### 7.100.3 Member Function Documentation

**void set ( TimeScheme *s*, real.t *time\_step* = theTimeStep, real.t *final\_time* = theFinalTime )**

Define data of the differential equation or system.

Parameters

|    |                   |                                                                                                                                                                                            |
|----|-------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>s</i>          | Choice of the scheme: To be chosen in the enumerated variable <i>TimeScheme</i> (see the presentation of the class)                                                                        |
| in | <i>time_step</i>  | Value of the time step. This value will be modified if an adaptive method is used. The default value for this parameter is the value given by the global variable <code>theTimeStep</code> |
| in | <i>final_time</i> | Value of the final time (time starts at 0). The default value for this parameter is the value given by the global variable <code>theFinalTime</code>                                       |

**void setPDE ( AbsEqua< real.t > &*eq* )**

Define partial differential equation to solve.

The used equation class must have been constructed using the [Mesh](#) instance

Parameters

|    |           |                                |
|----|-----------|--------------------------------|
| in | <i>eq</i> | Reference to equation instance |
|----|-----------|--------------------------------|

**void setRK4RHS ( Vect< real.t > &*f* )**

Set intermediate right-hand side vector for the Runge-Kutta method.

Parameters

|    |          |                           |
|----|----------|---------------------------|
| in | <i>f</i> | Vector containing the RHS |
|----|----------|---------------------------|

**void setInitial ( Vect< real.t > &*u* )**

Set initial condition for the system of differential equations.

Parameters

|    |          |                                                     |
|----|----------|-----------------------------------------------------|
| in | <i>u</i> | Vector containing initial condition for the unknown |
|----|----------|-----------------------------------------------------|

Remarks

If a second-order differential equation is to be solved, use the the same function with two initial vectors (one for the unknown, the second for its time derivative)

**void setInitial ( Vect< real\_t > &  $u$ , Vect< real\_t > &  $v$  )**

Set initial condition for a system of differential equations.

## Parameters

|                 |     |                                                                            |
|-----------------|-----|----------------------------------------------------------------------------|
| <code>in</code> | $u$ | Vector containing initial condition for the unknown                        |
| <code>in</code> | $v$ | Vector containing initial condition for the time derivative of the unknown |

## Note

This function can be used to provide solution at previous time step if a restarting procedure is used.

This member function is to be used only in the case of a second order system

**void setInitialRHS ( Vect< real.t > &f )**

Set initial RHS for a system of differential equations when the used scheme requires it.

Giving the right-hand side at initial time is sometimes required for high order methods like Runge-Kutta

## Parameters

|                 |     |                                                                                                  |
|-----------------|-----|--------------------------------------------------------------------------------------------------|
| <code>in</code> | $f$ | Vector containing right-hand side at initial time. This vector is helpful for high order methods |
|-----------------|-----|--------------------------------------------------------------------------------------------------|

## Note

This function can be used to provide solution at previous time step if a restarting procedure is used.

**void setNewmarkParameters ( real.t beta, real.t gamma )**

Define parameters for the Newmark scheme.

## Parameters

|                 |          |                                |
|-----------------|----------|--------------------------------|
| <code>in</code> | $\beta$  | Parameter beta [Default: 0.25] |
| <code>in</code> | $\gamma$ | Parameter gamma [Default: 0.5] |

**void setConstantMatrix ( )**

Say that matrix problem is constant.

This is useful if the linear system is solved by a factorization method but has no effect otherwise

**void setNonConstantMatrix ( )**

Say that matrix problem is variable.

This is useful if the linear system is solved by a factorization method but has no effect otherwise

**void setLinearSolver ( Iteration s = DIRECT\_SOLVER, Preconditioner p = DIAG\_PREC )**

Set linear solver data.

## Parameters

|    |   |                                                                                                                                                                                                                   |
|----|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | s | Solver identification parameter. To be chosen in the enumeration variable Iteration:<br>DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER<br>[Default: DIRECT_SOLVER] |
| in | p | Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner:<br>IDENT_PREC, DIAG_PREC, ILU_PREC [Default: DIAG_PREC]                                                         |

## Note

The argument *p* has no effect if the solver is DIRECT\_SOLVER

**void setVerbose ( int *v* = 0 )**

Set verbosity parameter:

- = 0, No output
- = 1, Print step label and time value
- = 2, Print step label, time value, time step and integration scheme

**real\_t runOneTimeStep ( )**

Run one time step.

## Returns

Value of new time step if this one is updated

**void run ( bool *opt* = false )**

Run the time stepping procedure.

## Parameters

|    |            |                                                                                                      |
|----|------------|------------------------------------------------------------------------------------------------------|
| in | <i>opt</i> | Flag to say if problem matrix is constant while time stepping (true) or not (Default value is false) |
|----|------------|------------------------------------------------------------------------------------------------------|

## Note

This argument is not used if the time stepping scheme is explicit

**void Assembly ( const Element & *el*, real\_t \* *b*, real\_t \* *A0*, real\_t \* *A1*, real\_t \* *A2* = NULL )**

Assemble element arrays into global matrix and right-hand side.

This member function is to be called from finite element equation classes

Parameters

|    |           |                                                                                           |
|----|-----------|-------------------------------------------------------------------------------------------|
| in | <i>el</i> | Reference to <a href="#">Element</a> class                                                |
| in | <i>b</i>  | Pointer to element right-hand side                                                        |
| in | <i>A0</i> | Pointer to matrix of 0-th order term (involving no time derivative)                       |
| in | <i>A1</i> | Pointer to matrix of first order term (involving time first derivative)                   |
| in | <i>A2</i> | Pointer to matrix of second order term (involving time second derivative) [Default: NULL] |

**void SAssembly ( const Side &sd, real\_t \* b, real\_t \* A = NULL )**

Assemble side arrays into global matrix and right-hand side.

This member function is to be called from finite element equation classes

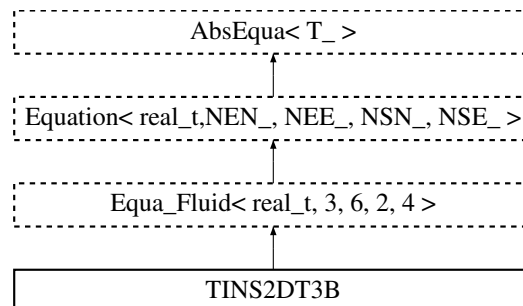
Parameters

|    |           |                                         |
|----|-----------|-----------------------------------------|
| in | <i>sd</i> | Reference to <a href="#">Side</a> class |
| in | <i>b</i>  | Pointer to side right-hand side         |
| in | <i>A</i>  | Pointer to matrix e) [Default: NULL]    |

## 7.101 TINS2DT3B Class Reference

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

Inheritance diagram for TINS2DT3B:



### Public Member Functions

- [TINS2DT3B](#) ()  
*Default Constructor.*
- [TINS2DT3B](#) ([Mesh](#) &mesh, [Vect](#)< [real\\_t](#) > &u, [Vect](#)< [real\\_t](#) > &p, [real\\_t](#) &ts, [real\\_t](#) Re=0.)  
*Constructor using mesh.*
- [~TINS2DT3B](#) ()  
*Destructor.*
- void [setInput](#) ([EqDataType](#) opt, [Vect](#)< [real\\_t](#) > &u)  
*Set equation input data.*
- int [runOneTimeStep](#) ()  
*Run one time step.*
- int [run](#) ()



*Run (in the case of one step run)*

- void **updateBC** (const **Element** &el, const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< T\_ > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **DiagBC** (int dof\_type=NODE.DOF, int dof=0)  
*Update element matrix to impose bc by diagonalization technique.*
- void **LocalNodeVector** (**Vect**< T\_ > &b)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be, int dof)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NEN\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementSideVector** (const **Vect**< T\_ > &b, **LocalVect**< T\_, NSE\_ > &be)  
*Localize **Element** Vector from a **Vect** instance.*
- void **ElementVector** (const **Vect**< T\_ > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize **Element** Vector.*
- void **SideVector** (const **Vect**< T\_ > &b)  
*Localize **Side** Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< T\_ > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< T\_ > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**TrMatrix**< T\_ > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**Vect**< T\_ > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (**PETScMatrix**< T\_ > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (**PETScVect**< T\_ > &b)

- Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< T\_ > &v)
- Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< T\_ > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< T\_ > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< T\_ > &x, [Vect](#)< T\_ > &b)
- Assemble product of side matrix by side vector into global vector.*
- size\_t [getNbNodes](#) () const
- Return number of element nodes.*
- size\_t [getNbEq](#) () const
- Return number of element equations.*
- void [setInitialSolution](#) (const [Vect](#)< T\_ > &u)
- Set initial solution (previous time step)*
- [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define a material property by an algebraic expression.*
- void [setMesh](#) ([Mesh](#) &m)
- Define mesh and renumber DOFs after removing imposed ones.*
- [Mesh](#) & [getMesh](#) () const
- Return reference to [Mesh](#) instance.*
- [LinearSolver](#)< T\_ > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)
- Choose solver for the linear system.*
- int [SolveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system.*

## Public Attributes

- **LocalMatrix**< T<sub>-</sub>, NEE<sub>-</sub>, NEE<sub>-</sub> > **eMat**  
*LocalMatrix* instance containing local matrix associated to current element.
- **LocalMatrix**< T<sub>-</sub>, NSE<sub>-</sub>, NSE<sub>-</sub> > **sMat**  
*LocalMatrix* instance containing local matrix associated to current side.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **ePrev**  
*LocalVect* instance containing local vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRHS**  
*LocalVect* instance containing local right-hand side vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NEE<sub>-</sub> > **eRes**  
*LocalVect* instance containing local residual vector associated to current element.
- **LocalVect**< T<sub>-</sub>, NSE<sub>-</sub> > **sRHS**  
*LocalVect* instance containing local right-hand side vector associated to current side.

## Protected Member Functions

- void **Viscosity** (const **real.t** &visc)  
Set (constant) Viscosity.
- void **Viscosity** (const string &exp)  
Set viscosity given by an algebraic expression.
- void **Density** (const **real.t** &dens)  
Set (constant) Viscosity.
- void **Density** (const string &exp)  
Set Density given by an algebraic expression.
- void **ThermalExpansion** (const **real.t** \*e)  
Set (constant) thermal expansion coefficient.
- void **ThermalExpansion** (const string &exp)  
Set thermal expansion coefficient given by an algebraic expression.
- void **setMaterial** ()  
Set material properties.
- void **Init** (const **Element** \*el)  
Set element arrays to zero.
- void **Init** (const **Side** \*sd)  
Set side arrays to zero.

### 7.101.1 Detailed Description

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

Note that members calculating element arrays have as an argument a double `coef` that will be multiplied by the contribution of the current element. This makes possible testing different algorithms.

### 7.101.2 Constructor & Destructor Documentation

**TINS2DT3B** ( **Mesh** & *mesh*, **Vect**< **real.t** > & *u*, **Vect**< **real.t** > & *p*, **real.t** & *ts*, **real.t** *Re* = 0. )

Constructor using mesh.

Parameters

|        |             |                                                                                                                                                                                                                                                          |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>mesh</i> | <a href="#">Mesh</a> instance                                                                                                                                                                                                                            |
| in,out | <i>u</i>    | <a href="#">Vect</a> instance containing initial velocity. This vector is updated during computations and will therefore contain velocity at each time step                                                                                              |
| out    | <i>p</i>    | <a href="#">Vect</a> instance that will contain pressure at nodes. This vector is updated during computations and will therefore contain pressure at each time step                                                                                      |
| in     | <i>ts</i>   | Time step                                                                                                                                                                                                                                                |
| in     | <i>Re</i>   | Reynolds number. The default value (0) means that no Reynolds number is given and problem data are supplied by material properties. If Re has any other value, then nondimensional form of the equations is assumed and material properties are ignored. |

### 7.101.3 Member Function Documentation

**void setInput ( EqDataType *opt*, Vect< real.t > & *u* )**

Set equation input data.

Parameters

|    |            |                                                                                                                                                                                                                                                                                                                                                                             |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>opt</i> | Parameter to select type of input (enumerated values) <ul style="list-style-type: none"> <li>INITIAL_FIELD: Initial temperature</li> <li>BOUNDARY_CONDITION_DATA: Boundary condition (Dirichlet)</li> <li>SOURCE_DATA: Heat source</li> <li>FLUX_DATA: Heat flux (Neumann boundary condition)</li> <li>VELOCITY_FIELD: Velocity vector (for the convection term)</li> </ul> |
| in | <i>u</i>   | Vector containing input data ( <a href="#">Vect</a> instance)                                                                                                                                                                                                                                                                                                               |

**void updateBC ( const Element & *el*, const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>el</i> | Reference to current element instance           |
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |

**void updateBC ( const Vect< T\_ > & *bc* )** [inherited]

Update Right-Hand side by taking into account essential boundary conditions.

Parameters

|    |           |                                                 |
|----|-----------|-------------------------------------------------|
| in | <i>bc</i> | Vector that contains imposed values at all DOFs |
|----|-----------|-------------------------------------------------|

Remarks

The current element is pointed by `_theElement`

**void DiagBC** ( *int dof\_type* = *NODE\_DOF*, *int dof* = 0 ) [inherited]

Update element matrix to impose bc by diagonalization technique.

## Parameters

|    |                 |                                                                                                                                                                                                                                                                                                                  |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <code>NODE.FIELD</code>, DOFs are supported by nodes [Default]</li> <li>• <code>ELEMENT.FIELD</code>, DOFs are supported by elements</li> <li>• <code>SIDE.FIELD</code>, DOFs are supported by sides</li> </ul> |
| in | <i>dof</i>      | DOF setting: <ul style="list-style-type: none"> <li>• <code>= 0</code>, All DOFs are taken into account [Default]</li> <li>• <code>!= 0</code>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>                                                                                                      |

**void LocalNodeVector ( Vect< T\_ > & b )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|    |          |                                                                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Reference to global vector to be localized. The resulting local vector can be accessed by attribute <code>ePrev</code> . This member function is to be used if a constructor with <a href="#">Element</a> was invoked. |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEE\_ > & be )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

## Remarks

All degrees of freedom are transferred to the local vector

**void ElementNodeVector ( const Vect< T\_ > & b, LocalVect< T\_, NEN\_ > & be, int dof )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

## Parameters

|     |            |                                                                             |
|-----|------------|-----------------------------------------------------------------------------|
| in  | <i>b</i>   | Global vector to be localized.                                              |
| out | <i>be</i>  | Local vector, the length of which is the total number of element equations. |
| in  | <i>dof</i> | Degree of freedom to transfer to the local vector                           |

## Remarks

Only the degree of freedom is transferred to the local vector

**void ElementNodeVectorSingleDOF ( const Vect< T\_ > & *b*, LocalVect< T\_, NEN\_ > & *be* )**  
[inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                                                             |
|-----|-----------|-----------------------------------------------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.                                              |
| out | <i>be</i> | Local vector, the length of which is the total number of element equations. |

Remarks

Vector *b* is assumed to contain only one degree of freedom by node.

**void ElementSideVector ( const Vect< T\_ > & *b*, LocalVect< T\_, NSE\_ > & *be* )** [inherited]

Localize [Element](#) Vector from a [Vect](#) instance.

Parameters

|     |           |                                      |
|-----|-----------|--------------------------------------|
| in  | <i>b</i>  | Global vector to be localized.       |
| out | <i>be</i> | Local vector, the length of which is |

**void ElementVector ( const Vect< T\_ > & *b*, int *dof\_type* = *NODE\_FIELD*, int *flag* = 0 )**  
[inherited]

Localize [Element](#) Vector.

Parameters

|    |                 |                                                                                                                                                                                                                                                                                                |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i>        | Global vector to be localized                                                                                                                                                                                                                                                                  |
| in | <i>dof_type</i> | DOF type option. To choose among the enumerated values: <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [Default]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> |
| in | <i>flag</i>     | Option to set: <ul style="list-style-type: none"> <li>• = 0, All DOFs are taken into account [Default]</li> <li>• != 0, Only DOF number <i>dof</i> is handled in the system</li> </ul> <p>The resulting local vector can be accessed by attribute <i>ePrev</i>.</p>                            |

Remarks

This member function is to be used if a constructor with [Element](#) was invoked. It uses the [Element](#) pointer *\_theElement*

**void SideVector ( const Vect< T\_ > & *b* )** [inherited]

Localize [Side](#) Vector.

Parameters

|    |          |                                                                                                                                                                                                                                                                                                                                                     |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>b</i> | Global vector to be localized <ul style="list-style-type: none"> <li>• <i>NODE_FIELD</i>, DOFs are supported by nodes [ default ]</li> <li>• <i>ELEMENT_FIELD</i>, DOFs are supported by elements</li> <li>• <i>SIDE_FIELD</i>, DOFs are supported by sides</li> </ul> <p>The resulting local vector can be accessed by attribute <i>ePrev</i>.</p> |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|



## Remarks

This member function is to be used if a constructor with [Side](#) was invoked. It uses the [Side](#) pointer `_theSide`

**void ElementNodeCoordinates ( )** [inherited]

Localize coordinates of element nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Side](#) pointer `_theSide`

**void SideNodeCoordinates ( )** [inherited]

Localize coordinates of side nodes.

Coordinates are stored in array `_x[0]`, `_x[1]`, ... which are instances of class [Point<real.t>](#)

## Remarks

This member function uses the [Element](#) pointer `_theElement`

**void ElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                                                                                                                                                   |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>A</i> | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|----------|---------------------------------------------------------------------------------------------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|          |                            |
|----------|----------------------------|
| <i>A</i> | Reference to global matrix |
|----------|----------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble element right-hand side vector into global one.

## Parameters

|     |                                            |
|-----|--------------------------------------------|
| $b$ | Reference to global right-hand side vector |
|-----|--------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( BMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                            |
|-----|------------------------------------------------------------|
| $A$ | Global matrix stored as a <a href="#">BMatrix</a> instance |
|-----|------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|     |                                                               |
|-----|---------------------------------------------------------------|
| $A$ | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|-----|---------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

|                 |     |                                                              |
|-----------------|-----|--------------------------------------------------------------|
| <code>in</code> | $A$ | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------------|-----|--------------------------------------------------------------|

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

Parameters

|    |     |                                                              |
|----|-----|--------------------------------------------------------------|
| in | $A$ | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|----|-----|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< T\_ > & v )** [inherited]

Assemble element vector into global one.

Parameters

|    |     |                                                |
|----|-----|------------------------------------------------|
| in | $v$ | Global vector ( <a href="#">Vect</a> instance) |
|----|-----|------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< T\_ > & A )** [inherited]

Assemble side matrix into global one.

Parameters

|  |     |                            |
|--|-----|----------------------------|
|  | $A$ | Reference to global matrix |
|--|-----|----------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< T\_ > & b )** [inherited]

Assemble side right-hand side vector into global one.

Parameters

|  |     |                                            |
|--|-----|--------------------------------------------|
|  | $b$ | Reference to global right-hand side vector |
|--|-----|--------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|  |     |                                                                                                                                                   |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|
|  | $A$ | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|--|-----|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                               |
|----|---|---------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----|---|---------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | A | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|----|---|--------------------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< T\_ > & v )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

|    |   |                                                |
|----|---|------------------------------------------------|
| in | v | Global vector ( <a href="#">Vect</a> instance) |
|----|---|------------------------------------------------|

Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< T\_ > \* A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|   |                                                                                                                                                   |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|
| A | Pointer to global matrix (abstract class: can be any of classes <a href="#">SkSMatrix</a> , <a href="#">SkMatrix</a> , <a href="#">SpMatrix</a> ) |
|---|---------------------------------------------------------------------------------------------------------------------------------------------------|

Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|          |                                                               |
|----------|---------------------------------------------------------------|
| <i>A</i> | Global matrix stored as an <a href="#">SkSMatrix</a> instance |
|----------|---------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SkMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">SpMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

|           |          |                                                              |
|-----------|----------|--------------------------------------------------------------|
| <i>in</i> | <i>A</i> | Global matrix stored as an <a href="#">TrMatrix</a> instance |
|-----------|----------|--------------------------------------------------------------|

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

|           |           |                                                               |
|-----------|-----------|---------------------------------------------------------------|
| <i>in</i> | <i>el</i> | Reference to <a href="#">Element</a> instance                 |
| <i>in</i> | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |

|     |          |                                                       |
|-----|----------|-------------------------------------------------------|
| out | <i>b</i> | Global vector to add ( <a href="#">Vect</a> instance) |
|-----|----------|-------------------------------------------------------|

**void AxbAssembly ( const Side & *sd*, const Vect< T\_ > & *x*, Vect< T\_ > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

|     |           |                                                               |
|-----|-----------|---------------------------------------------------------------|
| in  | <i>sd</i> | Reference to <a href="#">Side</a> instance                    |
| in  | <i>x</i>  | Global vector to multiply by ( <a href="#">Vect</a> instance) |
| out | <i>b</i>  | Global vector ( <a href="#">Vect</a> instance)                |

**real\_t setMaterialProperty ( const string & *exp*, const string & *prop* )** [inherited]

Define a material property by an algebraic expression.

Parameters

|    |             |                      |
|----|-------------|----------------------|
| in | <i>exp</i>  | Algebraic expression |
| in | <i>prop</i> | Property name        |

Returns

Return value in expression evaluation:

- =0, Normal evaluation
- !=0, An error message is displayed

**Mesh& getMesh ( ) const** [inherited]

Return reference to [Mesh](#) instance.

## Returns

Reference to [Mesh](#) instance

**void setSolver ( Iteration *ls*, Preconditioner *pc* = IDENT\_PREC )** [inherited]

Choose solver for the linear system.

Parameters

|    |           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----|-----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ls</i> | <p>Solver of the linear system. To choose among the enumerated values: DIRECT_SOLVER, CG_SOLVER, GMRES_SOLVER</p> <ul style="list-style-type: none"> <li>• DIRECT_SOLVER, Use a facorization solver [default]</li> <li>• CG_SOLVER, Conjugate Gradient iterative solver</li> <li>• CGS_SOLVER, Squared Conjugate Gradient iterative solver</li> <li>• BICG_SOLVER, BiConjugate Gradient iterative solver</li> <li>• BICG_STAB_SOLVER, BiConjugate Gradient Stabilized iterative solver</li> <li>• GMRES_SOLVER, GMRES iterative solver</li> <li>• QMR_SOLVER, QMR iterative solver</li> </ul> |
| in | <i>pc</i> | <p>Preconditioner to associate to the iterative solver. If the direct solver was chosen for the first argument this argument is not used. Otherwise choose among the enumerated values:</p> <ul style="list-style-type: none"> <li>• IDENT_PREC, Identity preconditioner (no preconditioning [default])</li> <li>• DIAG_PREC, Diagonal preconditioner</li> <li>• ILU_PREC, Incomplete LU factorization preconditioner</li> </ul>                                                                                                                                                              |

**int SolveLinearSystem ( Matrix< T\_ > \* A, Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Solve the linear system.

Parameters

|        |          |                                                                                 |
|--------|----------|---------------------------------------------------------------------------------|
| in     | <i>A</i> | Pointer to matrix of the system (Instance of class <a href="#">SpMatrix</a> )   |
| in     | <i>b</i> | Vector containing right-hand side                                               |
| in,out | <i>x</i> | Vector containing initial guess of solution on input, actual solution on output |

#### 7.101.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

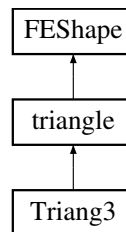
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.102 Triang3 Class Reference

Defines a 3-Node ( $P_1$ ) triangle.

Inheritance diagram for Triang3:



### Public Member Functions

- [Triang3](#) ()  
*Default Constructor.*
- [Triang3](#) (const [Element](#) \*el)  
*Constructor for an element.*
- [Triang3](#) (const [Side](#) \*sd)  
*Constructor for a side.*
- [~Triang3](#) ()  
*Destructor.*
- void [set](#) (const [Element](#) \*el)  
*Choose element by giving its pointer.*
- void [set](#) (const [Side](#) \*sd)  
*Choose side by giving its pointer.*
- [real\\_t](#) [Sh](#) (size\_t i, [Point](#)< [real\\_t](#) > s) const  
*Calculate shape function of node at a given point.*
- [Point](#)< [real\\_t](#) > [DSh](#) (size\_t i) const  
*Calculate derivatives of shape function of node i*
- [real\\_t](#) [getInterpolate](#) (const [Point](#)< [real\\_t](#) > &x, const [LocalVect](#)< [real\\_t](#), 3 > &v)  
*Return interpolated value at point of coordinate x*
- [real\\_t](#) [check](#) () const  
*Check element area and number of nodes.*
- [Point](#)< [real\\_t](#) > [Grad](#) (const [LocalVect](#)< [real\\_t](#), 3 > &u) const  
*Return constant gradient vector in triangle.*
- [real\\_t](#) [getMaxEdgeLength](#) () const  
*Return maximal edge length of triangle.*
- [real\\_t](#) [getMinEdgeLength](#) () const  
*Return minimal edge length of triangle.*
- [real\\_t](#) [getArea](#) ()  
*Return element area.*
- [Point](#)< [real\\_t](#) > [getCenter](#) () const  
*Return coordinates of center of element.*
- [Point](#)< [real\\_t](#) > [getCircumcenter](#) () const  
*Return coordinates of circumcenter of element.*



- `real_t getCircumRadius () const`  
*Return radius of circumscribed circle of triangle.*
- `real_t getInRadius () const`  
*Return radius of inscribed circle of triangle.*
- `Point< real_t > getRefCoord (const Point< real_t > &x) const`  
*Return reference coordinates of a point  $x$  in element.*
- `bool isIn (const Point< real_t > &x) const`  
*Check whether point  $x$  is in current triangle or not.*
- `bool isStrictlyIn (const Point< real_t > &x) const`  
*Check whether point  $x$  is strictly in current triangle (not on the boundary) or not.*
- `real_t Sh (size_t i) const`  
*Return shape function of node  $i$  at given point.*
- `real_t getDet () const`  
*Return determinant of jacobian.*
- `Point< real_t > getLocalPoint () const`  
*Localize a point in the element.*
- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`  
*Localize a point in the element.*

### 7.102.1 Detailed Description

Defines a 3-Node ( $P_1$ ) triangle.

The reference element is the rectangle triangle with two unit edges.

### 7.102.2 Constructor & Destructor Documentation

**Triang3 ( const Element \* *el* )**

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

**Triang3 ( const Side \* *sd* )**

Constructor for a side.

The constructed triangle is a side in a 3-D mesh.

### 7.102.3 Member Function Documentation

**real\_t Sh ( size\_t *i*, Point< real\_t > *s* ) const**

Calculate shape function of node at a given point.

Parameters

|                 |                |                                               |
|-----------------|----------------|-----------------------------------------------|
| <code>in</code> | <code>i</code> | Label (local) of node                         |
| <code>in</code> | <code>s</code> | Natural coordinates of node where to evaluate |

**real\_t check ( ) const**

Check element area and number of nodes.

Returns

- $> 0$ :  $m$  is the length
- $= 0$ : zero length ( $\Rightarrow$  Error)

**Point<real\_t> Grad ( const LocalVect< real\_t, 3 > & *u* ) const**

Return constant gradient vector in triangle.

Parameters

|                 |                |                                                  |
|-----------------|----------------|--------------------------------------------------|
| <code>in</code> | <code>u</code> | Local vector for which the gradient is evaluated |
|-----------------|----------------|--------------------------------------------------|

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

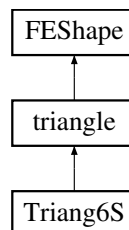
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.103 Triang6S Class Reference

Defines a 6-Node straight triangular finite element using  $P_2$  interpolation.

Inheritance diagram for Triang6S:



### Public Member Functions

- [Triang6S \(\)](#)  
*Default Constructor.*
- [Triang6S \(const Element \\*el\)](#)  
*Constructor for an element.*
- [~Triang6S \(\)](#)  
*Destructor.*
- [real\\_t Sh \(size\\_t i, const Point< real\\_t > &s\) const](#)  
*Calculate shape function of a node.*
- [Point< real\\_t > DSh \(size\\_t i, const Point< real\\_t > &s\) const](#)  
*Calculate derivatives of shape function of a node.*
- [Point< real\\_t > getCenter \(\) const](#)  
*Return coordinates of center of element.*
- [Point< real\\_t > Grad \(const LocalVect< real\\_t, 6 > &u, const Point< real\\_t > &s\) const](#)

- Return gradient vector in triangle at a given point.*

  - `real_t getMaxEdgeLength () const`

*Return maximal edge length of triangle.*

- `real_t getMinEdgeLength () const`

*Return minimal edge length of triangle.*

- `real_t getArea ()`

*Return element area.*

- `Point< real_t > getCircumcenter () const`

*Return coordinates of circumcenter of element.*

- `real_t getCircumRadius () const`

*Return radius of circumscribed circle of triangle.*

- `real_t getInRadius () const`

*Return radius of inscribed circle of triangle.*

- `Point< real_t > getRefCoord (const Point< real_t > &x) const`

*Return reference coordinates of a point  $x$  in element.*

- `bool isIn (const Point< real_t > &x) const`

*Check whether point  $x$  is in current triangle or not.*

- `bool isStrictlyIn (const Point< real_t > &x) const`

*Check whether point  $x$  is strictly in current triangle (not on the boundary) or not.*

- `real_t Sh (size_t i) const`

*Return shape function of node  $i$  at given point.*

- `real_t Sh (size_t i, Point< real_t > s) const`

*Calculate shape function of node  $i$  at a given point  $s$ .*

- `Point< real_t > DSh (size_t i) const`

*Return derivatives of shape function of node  $i$  at a given point.*

- `real_t getDet () const`

*Return determinant of jacobian.*

- `Point< real_t > getLocalPoint () const`

*Localize a point in the element.*

- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`

*Localize a point in the element.*

### 7.103.1 Detailed Description

Defines a 6-Node straight triangular finite element using  $P_2$  interpolation.

The reference element is the rectangle triangle with two unit edges.

### 7.103.2 Constructor & Destructor Documentation

**Triang6S ( const Element \* el )**

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

Parameters

---

|                 |                 |                                             |
|-----------------|-----------------|---------------------------------------------|
| <code>in</code> | <code>el</code> | Pointer to <a href="#">Element</a> instance |
|-----------------|-----------------|---------------------------------------------|

### 7.103.3 Member Function Documentation

**`real.t Sh ( size.t i, const Point< real.t > & s ) const`**

Calculate shape function of a node.

Parameters

|                 |                |                                                                      |
|-----------------|----------------|----------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | Local label of the node $1 \leq i \leq 6$                            |
| <code>in</code> | <code>s</code> | Local coordinates of the point where the shape function is evaluated |

**`Point<real.t> DSh ( size.t i, const Point< real.t > & s ) const`**

Calculate derivatives of shape function of a node.

Parameters

|                 |                |                                                                                      |
|-----------------|----------------|--------------------------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | Local label of node                                                                  |
| <code>in</code> | <code>s</code> | Local coordinates of the point where the gradient of the shape function is evaluated |

**`Point<real.t> Grad ( const LocalVect< real.t, 6 > & u, const Point< real.t > & s ) const`**

Return gradient vector in triangle at a given point.

Parameters

|                 |                |                                                                                      |
|-----------------|----------------|--------------------------------------------------------------------------------------|
| <code>in</code> | <code>s</code> | Local coordinates of the point where the gradient of the shape function is evaluated |
| <code>in</code> | <code>u</code> | Local vector for which the gradient is evaluated                                     |

**`real.t Sh ( size.t i, Point< real.t > s ) const`** [inherited]

Calculate shape function of node `i` at a given point `s`.

Parameters

|                 |                |                                                                                       |
|-----------------|----------------|---------------------------------------------------------------------------------------|
| <code>in</code> | <code>i</code> | Local node label                                                                      |
| <code>in</code> | <code>s</code> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**`Point<real.t> DSh ( size.t i ) const`** [inherited]

Return derivatives of shape function of node `i` at a given point.

If the transformation (Reference element -> Actual element) is not affine, member function `setLocal()` must have been called before in order to calculate relevant quantities.

Parameters

|                 |                |                                      |
|-----------------|----------------|--------------------------------------|
| <code>in</code> | <code>i</code> | Partial derivative index (1, 2 or 3) |
|-----------------|----------------|--------------------------------------|

**real.t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real.t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real.t> getLocalPoint ( const Point< real.t > & s ) const** [inherited]

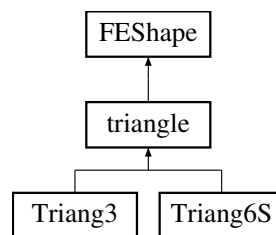
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.104 triangle Class Reference

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

Inheritance diagram for triangle:



### Public Member Functions

- **triangle ( )**  
*Default Constructor.*
- **triangle (const Element \*el)**  
*Constructor for an element.*
- **triangle (const Side \*sd)**  
*Constructor for a side.*
- **virtual ~triangle ( )**  
*Destructor.*
- **real.t getArea ( )**  
*Return element area.*
- **Point< real.t > getCenter ( ) const**  
*Return coordinates of center of element.*
- **Point< real.t > getCircumcenter ( ) const**  
*Return coordinates of circumcenter of element.*
- **real.t getCircumRadius ( ) const**  
*Return radius of circumscribed circle of triangle.*
- **real.t getInRadius ( ) const**

- Return radius of inscribed circle of triangle.*

  - `Point< real_t > getRefCoord (const Point< real_t > &x) const`

*Return reference coordinates of a point  $x$  in element.*
- `real_t getMaxEdgeLength () const`

*Return maximal edge length of triangle.*
- `real_t getMinEdgeLength () const`

*Return minimal edge length of triangle.*
- `bool isIn (const Point< real_t > &x) const`

*Check whether point  $x$  is in current triangle or not.*
- `bool isStrictlyIn (const Point< real_t > &x) const`

*Check whether point  $x$  is strictly in current triangle (not on the boundary) or not.*
- `real_t Sh (size_t i) const`

*Return shape function of node  $i$  at given point.*
- `real_t Sh (size_t i, Point< real_t > s) const`

*Calculate shape function of node  $i$  at a given point  $s$ .*
- `Point< real_t > DSh (size_t i) const`

*Return derivatives of shape function of node  $i$  at a given point.*
- `real_t getDet () const`

*Return determinant of jacobian.*
- `Point< real_t > getLocalPoint () const`

*Localize a point in the element.*
- `Point< real_t > getLocalPoint (const Point< real_t > &s) const`

*Localize a point in the element.*

### 7.104.1 Detailed Description

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

### 7.104.2 Constructor & Destructor Documentation

**triangle ( const Element \* *el* )**

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

**triangle ( const Side \* *sd* )**

Constructor for a side.

The constructed triangle is a side in a 3-D mesh.

### 7.104.3 Member Function Documentation

**real\_t Sh ( size\_t *i*, Point< real\_t > *s* ) const** [inherited]

Calculate shape function of node  $i$  at a given point  $s$ .

Parameters

---

|    |          |                                                                                       |
|----|----------|---------------------------------------------------------------------------------------|
| in | <i>i</i> | Local node label                                                                      |
| in | <i>s</i> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**Point<real\_t> DSh ( size\_t *i* ) const** [inherited]

Return derivatives of shape function of node *i* at a given point.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

Parameters

|    |          |                                      |
|----|----------|--------------------------------------|
| in | <i>i</i> | Partial derivative index (1, 2 or 3) |
|----|----------|--------------------------------------|

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & *s* ) const** [inherited]

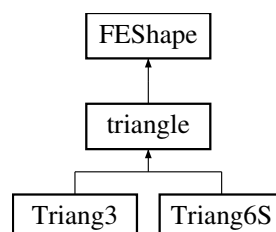
Localize a point in the element.

Return actual coordinates where *s* are coordinates in the reference element.

## 7.105 triangle Class Reference

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

Inheritance diagram for triangle:



### Public Member Functions

- [triangle](#) ()  
*Default Constructor.*
- [triangle](#) (const [Element](#) \*el)  
*Constructor for an element.*



- `triangle` (const `Side` \*sd)  
*Constructor for a side.*
- virtual `~triangle` ()  
*Destructor.*
- `real.t` `getArea` ()  
*Return element area.*
- `Point`< `real.t` > `getCenter` () const  
*Return coordinates of center of element.*
- `Point`< `real.t` > `getCircumcenter` () const  
*Return coordinates of circumcenter of element.*
- `real.t` `getCircumRadius` () const  
*Return radius of circumscribed circle of triangle.*
- `real.t` `getInRadius` () const  
*Return radius of inscribed circle of triangle.*
- `Point`< `real.t` > `getRefCoord` (const `Point`< `real.t` > &x) const  
*Return reference coordinates of a point  $x$  in element.*
- `real.t` `getMaxEdgeLength` () const  
*Return maximal edge length of triangle.*
- `real.t` `getMinEdgeLength` () const  
*Return minimal edge length of triangle.*
- bool `isIn` (const `Point`< `real.t` > &x) const  
*Check whether point  $x$  is in current triangle or not.*
- bool `isStrictlyIn` (const `Point`< `real.t` > &x) const  
*Check whether point  $x$  is strictly in current triangle (not on the boundary) or not.*
- `real.t` `Sh` (size\_t i) const  
*Return shape function of node  $i$  at given point.*
- `real.t` `Sh` (size\_t i, `Point`< `real.t` > s) const  
*Calculate shape function of node  $i$  at a given point  $s$ .*
- `Point`< `real.t` > `DSh` (size\_t i) const  
*Return derivatives of shape function of node  $i$  at a given point.*
- `real.t` `getDet` () const  
*Return determinant of jacobian.*
- `Point`< `real.t` > `getLocalPoint` () const  
*Localize a point in the element.*
- `Point`< `real.t` > `getLocalPoint` (const `Point`< `real.t` > &s) const  
*Localize a point in the element.*

### 7.105.1 Detailed Description

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

### 7.105.2 Constructor & Destructor Documentation

`triangle` ( const `Element` \* el )

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

**triangle ( const Side \* sd )**

Constructor for a side.

The constructed triangle is a side in a 3-D mesh.

### 7.105.3 Member Function Documentation

**real\_t Sh ( size\_t i, Point< real\_t > s ) const** [inherited]

Calculate shape function of node *i* at a given point *s*.

Parameters

|    |          |                                                                                       |
|----|----------|---------------------------------------------------------------------------------------|
| in | <i>i</i> | Local node label                                                                      |
| in | <i>s</i> | <a href="#">Point</a> in the reference triangle where the shape function is evaluated |

**Point<real\_t> DSh ( size\_t i ) const** [inherited]

Return derivatives of shape function of node *i* at a given point.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

Parameters

|    |          |                                      |
|----|----------|--------------------------------------|
| in | <i>i</i> | Partial derivative index (1, 2 or 3) |
|----|----------|--------------------------------------|

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( ) const** [inherited]

Localize a point in the element.

Return actual coordinates in the reference element. If the transformation (Reference element -> Actual element) is not affine, member function **setLocal()** must have been called before in order to calculate relevant quantities.

**Point<real\_t> getLocalPoint ( const Point< real\_t > & s ) const** [inherited]

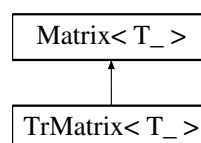
Localize a point in the element.

Return actual coordinates where *s* are coordinates in the reference element.

## 7.106 TrMatrix< T\_ > Class Template Reference

To handle tridiagonal matrices.

Inheritance diagram for TrMatrix< T\_ >:



## Public Member Functions

- [TrMatrix](#) ()  
*Default constructor.*
- [TrMatrix](#) (size\_t [size](#))  
*Constructor for a tridiagonal matrix with `size` rows.*
- [TrMatrix](#) (const [TrMatrix](#) &[m](#))  
*Copy Constructor.*
- [~TrMatrix](#) ()  
*Destructor.*
- void [Identity](#) ()  
*Define matrix as identity matrix.*
- void [Diagonal](#) ()  
*Define matrix as a diagonal one.*
- void [Diagonal](#) (const T\_ &[a](#))  
*Define matrix as a diagonal one with diagonal entries equal to `a`*
- void [Laplace1D](#) (real\_t [h](#))  
*Sets the matrix as the one for the Laplace equation in 1-D.*
- void [setSize](#) (size\_t [size](#))  
*Set size (number of rows) of matrix.*
- void [MultAdd](#) (const [Vect](#)< T\_ > &[x](#), [Vect](#)< T\_ > &[y](#)) const  
*Multiply matrix by vector `x` and add result to `y`.*
- void [MultAdd](#) (T\_ [a](#), const [Vect](#)< T\_ > &[x](#), [Vect](#)< T\_ > &[y](#)) const  
*Multiply matrix by vector `a*x` and add result to `y`.*
- void [Mult](#) (const [Vect](#)< T\_ > &[x](#), [Vect](#)< T\_ > &[y](#)) const  
*Multiply matrix by vector `x` and save result in `y`.*
- void [TMult](#) (const [Vect](#)< T\_ > &[x](#), [Vect](#)< T\_ > &[y](#)) const  
*Multiply transpose of matrix by vector `x` and save result in `y`.*
- void [Axy](#) (T\_ [a](#), const [TrMatrix](#)< T\_ > &[m](#))  
*Add to matrix the product of a matrix by a scalar.*
- void [Axy](#) (T\_ [a](#), const [Matrix](#)< T\_ > \*[m](#))  
*Add to matrix the product of a matrix by a scalar.*
- void [set](#) (size\_t [i](#), size\_t [j](#), const T\_ &[val](#))  
*Assign constant `val` to an entry  $(i, j)$  of the matrix.*
- void [add](#) (size\_t [i](#), size\_t [j](#), const T\_ &[val](#))  
*Add constant `val` value to an entry  $(i, j)$  of the matrix.*
- T\_ [operator](#)() (size\_t [i](#), size\_t [j](#)) const  
*Operator `()` (Constant version).*
- T\_ &[operator](#)() (size\_t [i](#), size\_t [j](#))  
*Operator `()` (Non constant version).*
- [TrMatrix](#)< T\_ > &[operator](#)= (const [TrMatrix](#)< T\_ > &[m](#))  
*Operator `=`.*
- [TrMatrix](#)< T\_ > &[operator](#)= (const T\_ &[x](#))  
*Operator `=` Assign matrix to identity times `x`.*
- [TrMatrix](#)< T\_ > &[operator](#)\*= (const T\_ &[x](#))  
*Operator `*=`.*
- int [solve](#) ([Vect](#)< T\_ > &[b](#))

- Solve a linear system with current matrix (forward and back substitution).*
- `int solve (const Vect< T_ > &b, Vect< T_ > &x)`  
*Solve a linear system with current matrix (forward and back substitution).*
- `T_ * get () const`  
*Return C-Array.*
- `T_ get (size_t i, size_t j) const`  
*Return entry (i, j) of matrix.*
- `size_t getNbRows () const`  
*Return number of rows.*
- `size_t getNbColumns () const`  
*Return number of columns.*
- `void setPenal (real_t p)`  
*Set Penalty Parameter (For boundary condition prescription).*
- `void setDiagonal ()`  
*Set the matrix as diagonal.*
- `void setDiagonal (Mesh &mesh)`  
*Initialize matrix storage in the case where only diagonal terms are stored.*
- `T_ getDiag (size_t k) const`  
*Return k-th diagonal entry of matrix.*
- `size_t size () const`  
*Return matrix dimension (Number of rows and columns).*
- `void Assembly (const Element &el, T_ *a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Element &el, const DMatrix< T_ > &a)`  
*Assembly of element matrix into global matrix.*
- `void Assembly (const Side &sd, T_ *a)`  
*Assembly of side matrix into global matrix.*
- `void Assembly (const Side &sd, const DMatrix< T_ > &a)`  
*Assembly of side matrix into global matrix.*
- `void Prescribe (Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.*
- `void Prescribe (int dof, int code, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.*
- `void Prescribe (Vect< T_ > &b, int flag=0)`  
*Impose by a penalty method a homegeneous (=0) essential boundary condition.*
- `void Prescribe (size_t dof, Vect< T_ > &b, const Vect< T_ > &u, int flag=0)`  
*Impose by a penalty method an essential boundary condition when only one DOF is treated.*
- `void PrescribeSide ()`  
*Impose by a penalty method an essential boundary condition when DOFs are supported by sides.*
- `virtual int Factor ()=0`  
*Factorize matrix. Available only if the storage class enables it.*
- `int FactorAndSolve (Vect< T_ > &b)`  
*Factorize matrix and solve the linear system.*
- `int FactorAndSolve (const Vect< T_ > &b, Vect< T_ > &x)`  
*Factorize matrix and solve the linear system.*
- `size_t getLength () const`

- Return number of stored terms in matrix.
- `int isDiagonal () const`  
Say if matrix is diagonal or not.
- `int isFactorized () const`  
Say if matrix is factorized or not.
- `virtual size_t getColInd (size_t i) const`  
Return Column index for column *i* (See the description for class *SpMatrix*).
- `virtual size_t getRowPtr (size_t i) const`  
Return Row pointer for row *i* (See the description for class *SpMatrix*).
- `T_ operator() (size_t i) const`  
Operator () with one argument (Constant version).
- `T_ & operator() (size_t i)`  
Operator () with one argument (Non Constant version).
- `T_ & operator[] (size_t k)`  
Operator [] (Non constant version).
- `T_ operator[] (size_t k) const`  
Operator [] (Constant version).
- `Matrix & operator+= (const Matrix< T_ > &m)`  
Operator +=.
- `Matrix & operator+= (const T_ &x)`  
Operator +=.
- `Matrix & operator-= (const Matrix< T_ > &m)`  
Operator -=.
- `Matrix & operator-= (const T_ &x)`  
Operator -=.

### 7.106.1 Detailed Description

`template<class T_>class OFELI::TrMatrix< T_ >`

To handle tridiagonal matrices.

This class enables storing and manipulating tridiagonal matrices. The template parameter is the type of matrix entries

Template Parameters

|                 |                                                 |
|-----------------|-------------------------------------------------|
| <code>T_</code> | Data type (double, float, complex<double>, ...) |
|-----------------|-------------------------------------------------|

### 7.106.2 Constructor & Destructor Documentation

`TrMatrix ( )`

Default constructor.

Initialize a zero dimension tridiagonal matrix

### 7.106.3 Member Function Documentation

`void Laplace1D ( real_t h )`

Sets the matrix as the one for the Laplace equation in 1-D.

The matrix is initialized as the one resulting from  $P_1$  finite element discretization of the classical elliptic operator  $-u'' = f$  with homogeneous Dirichlet boundary conditions

## Remarks

This function is available for real valued matrices only.

## Parameters

|    |     |                              |
|----|-----|------------------------------|
| in | $h$ | Mesh size (assumed constant) |
|----|-----|------------------------------|

**void setSize ( size\_t size )**

Set size (number of rows) of matrix.

## Parameters

|    |        |                             |
|----|--------|-----------------------------|
| in | $size$ | Number of rows and columns. |
|----|--------|-----------------------------|

**void Apxy ( T\_ a, const TrMatrix< T\_ > & m )**

Add to matrix the product of a matrix by a scalar.

## Parameters

|    |     |                                                                          |
|----|-----|--------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                    |
| in | $m$ | Matrix by which a is multiplied. The result is added to current instance |

**void Apxy ( T\_ a, const Matrix< T\_ > \* m ) [virtual]**

Add to matrix the product of a matrix by a scalar.

## Parameters

|    |     |                                                                          |
|----|-----|--------------------------------------------------------------------------|
| in | $a$ | Scalar to premultiply                                                    |
| in | $m$ | Matrix by which a is multiplied. The result is added to current instance |

Implements [Matrix< T\\_ >](#).

**T\_ operator() ( size\_t i, size\_t j ) const [virtual]**

Operator () (Constant version).

## Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**T\_ & operator() ( size\_t i, size\_t j ) [virtual]**

Operator () (Non constant version).

## Parameters

|    |     |              |
|----|-----|--------------|
| in | $i$ | Row index    |
| in | $j$ | Column index |

Implements [Matrix< T\\_ >](#).

**TrMatrix< T\_ > & operator= ( const TrMatrix< T\_ > & m )**

Operator =.

Copy matrix *m* to current matrix instance.

**TrMatrix< T\_ > & operator\*= ( const T\_ & x )**

Operator \*.

Premultiply matrix entries by constant value *x*.

**int solve ( Vect< T\_ > & b )** [virtual]

Solve a linear system with current matrix (forward and back substitution).

Parameters

|        |          |                                                                                              |
|--------|----------|----------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output. |
|--------|----------|----------------------------------------------------------------------------------------------|

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

**Warning:** Matrix is modified after this function.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )**

Solve a linear system with current matrix (forward and back substitution).

Parameters

|     |          |                                                              |
|-----|----------|--------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side. |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution.        |

Returns

- 0 if solution was normally performed,
- *n* if the *n*-th pivot is null.

**Warning:** Matrix is modified after this function.

**void setDiagonal ( Mesh & mesh )** [inherited]

Initialize matrix storage in the case where only diagonal terms are stored.

This member function is to be used for explicit time integration schemes

**T\_ getDiag ( size\_t k ) const** [inherited]

Return *k*-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**void Assembly ( const Element & el, T\_ \* a )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a C-array.

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>el</i> | Pointer to element instance                 |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a C-array |

**void Assembly ( const Element & *el*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of element matrix into global matrix.

Case where element matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                      |
|----|-----------|----------------------------------------------------------------------|
| in | <i>el</i> | Pointer to element instance                                          |
| in | <i>a</i>  | <a href="#">Element</a> matrix as a <a href="#">DMatrix</a> instance |

**void Assembly ( const Side & *sd*, T\_ \* *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a C-array.

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a C-array instance |

**void Assembly ( const Side & *sd*, const DMatrix< T\_ > & *a* )** [inherited]

Assembly of side matrix into global matrix.

Case where side matrix is given by a [DMatrix](#) instance.

Parameters

|    |           |                                                                   |
|----|-----------|-------------------------------------------------------------------|
| in | <i>sd</i> | Pointer to side instance                                          |
| in | <i>a</i>  | <a href="#">Side</a> matrix as a <a href="#">DMatrix</a> instance |

**void Prescribe ( Vect< T\_ > & *b*, const Vect< T\_ > & *u*, int *flag* = 0 )** [inherited]

Impose by a penalty method an essential boundary condition, using the [Mesh](#) instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set-Penal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |



**void Prescribe ( int dof, int code, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )**  
[inherited]

Impose by a penalty method an essential boundary condition to a given degree of freedom for a given code.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Degree of freedom for which a boundary condition is to be enforced                                                                           |
| in     | <i>code</i> | Code for which a boundary condition is to be enforced                                                                                        |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that contains imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( Vect< T\_ > & b, int flag = 0 )** [inherited]

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void Prescribe ( size\_t dof, Vect< T\_ > & b, const Vect< T\_ > & u, int flag = 0 )** [inherited]

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function **setPenal**.

Parameters

|        |             |                                                                                                                                              |
|--------|-------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| in     | <i>dof</i>  | Label of the concerned degree of freedom (DOF).                                                                                              |
| in,out | <i>b</i>    | <a href="#">Vect</a> instance that contains right-hand side.                                                                                 |
| in     | <i>u</i>    | <a href="#">Vect</a> instance that conatins imposed valued at DOFs where they are to be imposed.                                             |
| in     | <i>flag</i> | Parameter to determine whether only the right-hand side is to be modified (dof>0) or both matrix and right-hand side (dof=0, default value). |

**void PrescribeSide ( )** [inherited]

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **setPenal(..)**.

**int FactorAndSolve ( Vect< T\_ > & b )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|        |          |                                                                                             |
|--------|----------|---------------------------------------------------------------------------------------------|
| in,out | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side on input and solution on output |
|--------|----------|---------------------------------------------------------------------------------------------|

**int FactorAndSolve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [inherited]

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

|     |          |                                                             |
|-----|----------|-------------------------------------------------------------|
| in  | <i>b</i> | <a href="#">Vect</a> instance that contains right-hand side |
| out | <i>x</i> | <a href="#">Vect</a> instance that contains solution        |

Returns

- 0 if solution was normally performed
- n if the n-th pivot is nul

**int isFactorized ( ) const** [inherited]

Say if matrix is factorized or not.

If the matrix was not factorized, the class does not allow solving by a direct solver.

**T\_ operator() ( size\_t i ) const** [inherited]

Operator () with one argument (Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|    |          |             |
|----|----------|-------------|
| in | <i>i</i> | entry index |
|----|----------|-------------|

**T\_& operator() ( size\_t i )** [inherited]

Operator () with one argument (Non Constant version).

Returns i-th position in the array storing matrix entries. The first entry is at location 1. Entries are stored row by row.

Parameters

|                 |                |             |
|-----------------|----------------|-------------|
| <code>in</code> | <code>i</code> | entry index |
|-----------------|----------------|-------------|

**T\_& operator[] ( size\_t k )** [inherited]

Operator [] (Non constant version).

Returns k-th stored element in matrix Index k starts at 0.

**T\_ operator[] ( size\_t k ) const** [inherited]

Operator [] (Constant version).

Returns k-th stored element in matrix Index k starts at 0.

**Matrix& operator+= ( const Matrix< T\_ > & m )** [inherited]

Operator +=.

Add matrix m to current matrix instance.

**Matrix& operator+= ( const T\_ & x )** [inherited]

Operator +=.

Add constant value x to all matrix entries.

**Matrix& operator-= ( const Matrix< T\_ > & m )** [inherited]

Operator -=.

Subtract matrix m from current matrix instance.

**Matrix& operator-= ( const T\_ & x )** [inherited]

Operator -=.

Subtract constant value x from all matrix entries.

## 7.107 UserData< T\_ > Class Template Reference

Abstract class to define by user various problem data.

### Public Member Functions

- [UserData](#) ()  
*Default Constructor.*
- [UserData](#) (const class [Mesh](#) &mesh)  
*Constructor using mesh instance.*
- virtual [~UserData](#) ()  
*Destructor.*
- void [setTime](#) (real\_t time)  
*Set time value.*
- void [setDBC](#) (Vect< T\_ > &b)  
*Set Dirichlet Boundary Conditions.*
- void [setInitialData](#) (Vect< T\_ > &b)  
*Set initial data.*

- void `setBodyForce` (`Vect< T_ > &b`)  
Set Nodewise Body Force using a `Vect` instance.
- void `setSurfaceForce` (`Vect< T_ > &b`)  
Set Surface Force.
- virtual `T_ BoundaryCondition` (`Point< real.t > x`, int `code`, `real.t` `time=0.`, size\_t `dof=1`)  
Define boundary condition to impose at point of coordinates  $x$ , with code `code` at time `time`, for DOF `dof`
- virtual `T_ BodyForce` (`Point< real.t > x`, `real.t` `time=0.`, size\_t `dof=1`)  
Define body force to impose at point of coordinates  $x$ , with code `code` at time `time`, for DOF `dof`
- virtual `T_ SurfaceForce` (`Point< real.t > x`, int `code`, `real.t` `time=0.`, size\_t `dof=1`)  
Define surface force to impose at point of coordinates  $x$ , with code `code` at time `time`, for DOF `dof`
- virtual `T_ InitialData` (`Point< real.t > x`, size\_t `dof=1`)  
Define initial data to impose at point of coordinates  $x$ , for DOF `dof`

### 7.107.1 Detailed Description

**template<class T\_>class OFELI::UserData< T\_ >**

Abstract class to define by user various problem data.

The user has to implement a class that derives from the present one where the virtual functions are implemented.

Template Parameters

|                         |                                                 |
|-------------------------|-------------------------------------------------|
| <code>&lt;T_&gt;</code> | Data type (real.t, float, complex<real.t>, ...) |
|-------------------------|-------------------------------------------------|

### 7.107.2 Constructor & Destructor Documentation

**UserData ( const class Mesh & *mesh* )**

Constructor using mesh instance.

Parameters

|             |                                         |
|-------------|-----------------------------------------|
| <i>mesh</i> | Reference to <code>Mesh</code> instance |
|-------------|-----------------------------------------|

### 7.107.3 Member Function Documentation

**void setDBC ( Vect< T\_ > & *b* )**

Set Dirichlet Boundary Conditions.

This function loops over all nodes and calls for each node the member function BoundaryCondition to assign the value defined by it

Parameters

|     |          |                                                                                                           |
|-----|----------|-----------------------------------------------------------------------------------------------------------|
| out | <i>b</i> | Vector that contains boundary conditions at nodes This vector must be sized before invoking this function |
|-----|----------|-----------------------------------------------------------------------------------------------------------|

**void setInitialData ( Vect< T\_ > & *b* )**

Set initial data.

This function loops over all nodes and calls for each node the member function InitialData to assign the value defined by it

Parameters

|     |          |                                                                                                    |
|-----|----------|----------------------------------------------------------------------------------------------------|
| out | <i>b</i> | Vector that contains initial data at nodes This vector must be sized before invoking this function |
|-----|----------|----------------------------------------------------------------------------------------------------|

**void setBodyForce ( Vect< T\_ > & *b* )**

Set Nodewise Body Force using a Vect instance.

Parameters

|    |          |                                                  |
|----|----------|--------------------------------------------------|
| in | <i>b</i> | Vector containing body forces at nodes to impose |
|----|----------|--------------------------------------------------|

This function loops over all nodes and calls for each node the member function BodyForce to assign the value defined by it

Parameters

|     |          |                                                                                                   |
|-----|----------|---------------------------------------------------------------------------------------------------|
| out | <i>b</i> | Vector that contains body forces at nodes This vector must be sized before invoking this function |
|-----|----------|---------------------------------------------------------------------------------------------------|

**void setSurfaceForce ( Vect< T\_ > & *b* )**

Set Surface Force.

Parameters

|    |          |                                                     |
|----|----------|-----------------------------------------------------|
| in | <i>b</i> | Vector containing surface forces at nodes to impose |
|----|----------|-----------------------------------------------------|

This function loops over all nodes and calls for each node the member function SurfaceForce to assign the value defined by it

Parameters

|     |          |                                                                                                   |
|-----|----------|---------------------------------------------------------------------------------------------------|
| out | <i>b</i> | Vector that contains body forces at nodes This vector must be sized before invoking this function |
|-----|----------|---------------------------------------------------------------------------------------------------|

**virtual T\_ BoundaryCondition ( Point< real\_t > *x*, int *code*, real\_t *time* = 0., size\_t *dof* = 1 )**  
[virtual]

Define boundary condition to impose at point of coordinates *x*, with code *code* at time *time*, for DOF *dof*

Function to implement by user

Parameters

|    |             |                                                             |
|----|-------------|-------------------------------------------------------------|
| in | <i>x</i>    | Coordinates of point at which the value is to be prescribed |
| in | <i>code</i> | Code of node for which the value is to be prescribed        |
| in | <i>time</i> | Value of time [Default: 0.]                                 |
| in | <i>dof</i>  | Corresponding degree of freedom [Default: 1]                |

Returns

Value of boundary condition to prescribe corresponding to these parameters

**virtual T\_ BodyForce ( Point< real\_t > *x*, real\_t *time* = 0., size\_t *dof* = 1 )** [virtual]

Define body force to impose at point of coordinates *x*, with code *code* at time *time*, for DOF *dof*

Function to implement by user

Parameters

|    |        |                                                       |
|----|--------|-------------------------------------------------------|
| in | $x$    | Coordinates of point at which the body force is given |
| in | $time$ | Value of time [Default: 0.]                           |
| in | $dof$  | Corresponding degree of freedom [Default: 1]          |

Returns

Value of body force corresponding to these parameters

**virtual T\_ SurfaceForce ( Point< real\_t >  $x$ , int  $code$ , real\_t  $time = 0.$ , size\_t  $dof = 1$  )**  
[virtual]

Define surface force to impose at point of coordinates  $x$ , with code  $code$  at time  $time$ , for DOF  $dof$

Function to implement by user

Parameters

|    |        |                                                          |
|----|--------|----------------------------------------------------------|
| in | $x$    | Coordinates of point at which the surface force is given |
| in | $code$ | Code of node for which the surface force is given        |
| in | $time$ | Value of time [Default: 0.]                              |
| in | $dof$  | Corresponding degree of freedom [Default: 1]             |

Returns

Value of surface force corresponding to these parameters

**virtual T\_ InitialData ( Point< real\_t >  $x$ , size\_t  $dof = 1$  )** [virtual]

Define initial data to impose at point of coordinates  $x$ , for DOF  $dof$

Function to implement by user

Parameters

|    |       |                                                          |
|----|-------|----------------------------------------------------------|
| in | $x$   | Coordinates of point at which the surface force is given |
| in | $dof$ | Corresponding degree of freedom [Default: 1]             |

Returns

Value of initial data corresponding to these parameters

## 7.108 Vect< T\_ > Class Template Reference

To handle general purpose vectors.

### Public Types

- typedef Eigen::Matrix< T\_, Eigen::Dynamic, 1 > [VectorX](#)

*This type is the vector type in the Eigen library.*

## Public Member Functions

- `Vect ()`  
*Default Constructor. Initialize a zero-length vector.*
- `Vect (size_t n)`  
*Constructor setting vector size.*
- `Vect (size_t nx, size_t ny)`  
*Constructor of a 2-D index vector.*
- `Vect (size_t nx, size_t ny, size_t nz)`  
*Constructor of a 3-D index vector.*
- `Vect (size_t n, T_ *x)`  
*Create an instance of class `Vect` as an image of a C/C++ array.*
- `Vect (Mesh &m, int nb_dof=0, int dof_type=NODE_FIELD)`  
*Constructor with a mesh instance.*
- `Vect (Mesh &m, string name, real_t t=0.0, int nb_dof=0, int dof_type=NODE_FIELD)`  
*Constructor with a mesh instance giving name and time for vector.*
- `Vect (const Element *el, const Vect< T_ > &v)`  
*Constructor of an element vector.*
- `Vect (const Side *sd, const Vect< T_ > &v)`  
*Constructor of a side vector.*
- `Vect (const Vect< T_ > &v, const Vect< T_ > &bc)`  
*Constructor using boundary conditions.*
- `Vect (const Vect< T_ > &v, size_t nb_dof, size_t first_dof)`  
*Constructor to select some components of a given vector.*
- `Vect (const Vect< T_ > &v)`  
*Copy constructor.*
- `Vect (const Vect< T_ > &v, size_t n)`  
*Constructor to select one component from a given 2 or 3-component vector.*
- `Vect (size_t d, const Vect< T_ > &v, const string &name=" ")`  
*Constructor that extracts some degrees of freedom (components) from given instance of `Vect`.*
- `Vect (const VectorX &v)`  
*Constructor that copies the vector from a Eigen Vector instance.*
- `~Vect ()`  
*Destructor.*
- `void set (const T_ *v, size_t n)`  
*Initialize vector with a c-array.*
- `void select (const Vect< T_ > &v, size_t nb_dof=0, size_t first_dof=1)`  
*Initialize vector with another `Vect` instance.*
- `void set (const string &exp, size_t dof=1)`  
*Initialize vector with an algebraic expression.*
- `void set (const string &exp, const Vect< real_t > &x)`  
*Initialize vector with an algebraic expression.*
- `void set (const Mesh &ms, const string &exp, size_t dof=1)`  
*Initialize vector with an algebraic expression with providing mesh data.*
- `void set (const Vect< real_t > &x, const string &exp)`  
*Initialize vector with an algebraic expression.*
- `void setMesh (Mesh &m, size_t nb_dof=0, size_t dof_type=NODE_FIELD)`

- Define mesh class to size vector.*
- `size_t size () const`  
*Return vector (global) size.*
- `void setSize (size_t nx, size_t ny=1, size_t nz=1)`  
*Set vector size (for 1-D, 2-D or 3-D cases)*
- `void resize (size_t n)`  
*Set vector size.*
- `void resize (size_t n, T_ v)`  
*Set vector size and initialize to a constant value.*
- `void setDOFType (int dof_type)`  
*Set DOF type of vector.*
- `void setDG (int degree=1)`  
*Set Discontinuous Galerkin type vector.*
- `size_t getNbDOF () const`  
*Return vector number of degrees of freedom.*
- `size_t getNb () const`  
*Return vector number of entities (nodes, elements or sides)*
- `Mesh & getMesh () const`  
*Return Mesh instance.*
- `bool WithMesh () const`  
*Return true if vector contains a Mesh pointer, false if not.*
- `int getDOFType () const`
- `void setTime (real_t t)`  
*Set time value for vector.*
- `real_t getTime () const`  
*Get time value for vector.*
- `void setName (string name)`  
*Set name of vector.*
- `string getName () const`  
*Get name of vector.*
- `real_t getNorm1 () const`  
*Calculate 1-norm of vector.*
- `real_t getNorm2 () const`  
*Calculate 2-norm (Euclidean norm) of vector.*
- `real_t getNormMax () const`  
*Calculate Max-norm (Infinite norm) of vector.*
- `real_t getWNorm1 () const`  
*Calculate weighted 1-norm of vector The wighted 1-norm is the 1-Norm of the vector divided by its size.*
- `real_t getWNorm2 () const`  
*Calculate weighted 2-norm of vector.*
- `T_ getMin () const`  
*Calculate Min value of vector entries.*
- `T_ getMax () const`  
*Calculate Max value of vector entries.*
- `size_t getNx () const`  
*Return number of grid points in the x-direction if grid indexing is set.*
- `size_t getNy () const`



- Return number of grid points in the y-direction if grid indexing is set.*

  - `size_t getNz () const`
- Return number of grid points in the z-direction if grid indexing is set.*

  - `void setNodeBC (Mesh &m, int code, T_ val, size_t dof=1)`

*Assign a given value to components of vector with given code.*
- `void setNodeBC (Mesh &m, int code, const string &exp, size_t dof=1)`

*Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.*
- `void setNodeBC (int code, T_ val, size_t dof=1)`

*Assign a given value to components of vector with given code.*
- `void setNodeBC (int code, const string &exp, size_t dof=1)`

*Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.*
- `void removeBC (const Mesh &ms, const Vect< T_ > &v, int dof=0)`

*Remove boundary conditions.*
- `void removeBC (const Vect< T_ > &v, int dof=0)`

*Remove boundary conditions.*
- `void transferBC (const Vect< T_ > &bc, int dof=0)`

*Transfer boundary conditions to the vector.*
- `void insertBC (Mesh &m, const Vect< T_ > &v, const Vect< T_ > &bc, int dof=0)`

*Insert boundary conditions.*
- `void insertBC (Mesh &m, const Vect< T_ > &v, int dof=0)`

*Insert boundary conditions.*
- `void insertBC (const Vect< T_ > &v, const Vect< T_ > &bc, int dof=0)`

*Insert boundary conditions.*
- `void insertBC (const Vect< T_ > &v, int dof=0)`

*Insert boundary conditions.*
- `void Assembly (const Element &el, const Vect< T_ > &b)`

*Assembly of element vector into current instance.*
- `void Assembly (const Element &el, const T_ *b)`

*Assembly of element vector (as C-array) into Vect instance.*
- `void Assembly (const Side &sd, const Vect< T_ > &b)`

*Assembly of side vector into Vect instance.*
- `void Assembly (const Side &sd, T_ *b)`

*Assembly of side vector (as C-array) into Vect instance.*
- `void getGradient (class Vect< T_ > &v)`

*Evaluate the discrete Gradient vector of the current vector.*
- `void getGradient (Vect< Point< T_ > > &v)`

*Evaluate the discrete Gradient vector of the current vector.*
- `void getCurl (Vect< T_ > &v)`

*Evaluate the discrete curl vector of the current vector.*
- `void getCurl (Vect< Point< T_ > > &v)`

*Evaluate the discrete curl vector of the current vector.*
- `void getSCurl (Vect< T_ > &v)`

*Evaluate the discrete scalar curl in 2-D of the current vector.*
- `void getDivergence (Vect< T_ > &v)`

*Evaluate the discrete Divergence of the current vector.*

- `real_t getAverage` (const `Element` &el, int type) const  
*Return average value of vector in a given element.*
- void `save` (string file, int opt)  
*Save vector in a file according to a given format.*
- `Vect< T_ > & MultAdd` (const `Vect< T_ >` &x, const T\_ &a)  
*Multiply by a constant then add to a vector.*
- void `Axpy` (T\_ a, const `Vect< T_ >` &x)  
*Add to vector the product of a vector by a scalar.*
- void `set` (size\_t i, T\_ val)  
*Assign a value to an entry for a 1-D vector.*
- void `set` (size\_t i, size\_t j, T\_ val)  
*Assign a value to an entry for a 2-D vector.*
- void `set` (size\_t i, size\_t j, size\_t k, T\_ val)  
*Assign a value to an entry for a 3-D vector.*
- void `add` (size\_t i, T\_ val)  
*Add a value to an entry for a 1-index vector.*
- void `add` (size\_t i, size\_t j, T\_ val)  
*Add a value to an entry for a 2-index vector.*
- void `add` (size\_t i, size\_t j, size\_t k, T\_ val)  
*Assign a value to an entry for a 3-index vector.*
- void `clear` ()  
*Clear vector: Set all its elements to zero.*
- T\_ & `operator[]` (size\_t i)  
*Operator [] (Non constant version)*
- T\_ `operator[]` (size\_t i) const  
*Operator [] (Constant version)*
- T\_ & `operator()` (size\_t i)  
*Operator () (Non constant version)*
- T\_ `operator()` (size\_t i) const  
*Operator () (Constant version)*
- T\_ & `operator()` (size\_t i, size\_t j)  
*Operator () with 2-D indexing (Non constant version, case of a grid vector).*
- T\_ `operator()` (size\_t i, size\_t j) const  
*Operator () with 2-D indexing (Constant version).*
- T\_ & `operator()` (size\_t i, size\_t j, size\_t k)  
*Operator () with 3-D indexing (Non constant version).*
- T\_ `operator()` (size\_t i, size\_t j, size\_t k) const  
*Operator () with 3-D indexing (Constant version).*
- `Vect< T_ > & operator=` (const `Vect< T_ >` &v)  
*Operator = between vectors.*
- `Vect< T_ > & operator=` (const `VectorX` &v)  
*Operator = for an instance of VectorX*
- void `operator=` (string s)  
*Operator =*
- void `setUniform` (T\_ vmin, T\_ delta, T\_ vmax)  
*Initialize vector entries by setting extremal values and interval.*

- `Vect< T_ > & operator=` (const T\_ &a)  
*Operator =*
- `Vect< T_ > & operator+=` (const Vect< T\_ > &v)  
*Operator +=*
- `Vect< T_ > & operator+=` (const T\_ &a)  
*Operator +=*
- `Vect< T_ > & operator-=` (const Vect< T\_ > &v)  
*Operator -=*
- `Vect< T_ > & operator-=` (const T\_ &a)  
*Operator -=*
- `Vect< T_ > & operator*=` (const T\_ &a)  
*Operator \*=*
- `Vect< T_ > & operator/=` (const T\_ &a)  
*Operator /=*
- `void push.back` (const T\_ &v)  
*Add an entry to the vector.*
- `const Mesh & getMeshPtr` () const  
*Return reference to Mesh instance.*
- `T_ operator,` (const Vect< T\_ > &v) const  
*Return Dot (scalar) product of two vectors.*
- `operator VectorX` () const  
*Casting operator.*

### 7.108.1 Detailed Description

**template<class T\_>class OFELI::Vect< T\_ >**

To handle general purpose vectors.

This template class enables defining and manipulating vectors of various data types. It inherits from the class `std::vector`. An instance of class `Vect` can be:

- A simple vector of given size
- A vector with up to three indices, *i.e.*, an entry of the vector can be `a(i)`, `a(i, j)` or `a(i, j, k)`. This feature is useful, for instance, in the case of a structured grid
- A vector associate to a finite element mesh. In this case, a constructor uses a reference to the `Mesh` instance. The size of the vector is by default equal to the number of nodes x the number of degrees of freedom by node. If the degrees of freedom are supported by elements or sides, then the vector is sized accordingly

Operators `=`, `[]` and `()` are overloaded so that one can write for instance:

```
Vect<real_t> u(10), v(10);
v = -1.0;
u = v;
u(3) = -2.0;
```

to set vector `v` entries to `-1`, copy vector `v` into vector `u` and assign third entry of `v` to `-2`. Note that entries of `v` are here `v(1)`, `v(2)`, ..., `v(10)`, *i.e.* vector entries start at index `1`.

## Template Parameters

|           |                                                 |
|-----------|-------------------------------------------------|
| <i>T_</i> | Data type (real.t, float, complex<real.t>, ...) |
|-----------|-------------------------------------------------|

**7.108.2 Constructor & Destructor Documentation****Vect ( size.t *n* )**

Constructor setting vector size.

Parameters

|           |          |                |
|-----------|----------|----------------|
| <i>in</i> | <i>n</i> | Size of vector |
|-----------|----------|----------------|

**Vect ( size.t *nx*, size.t *ny* )**

Constructor of a 2-D index vector.

This constructor can be used for instance for a 2-D grid vector

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <i>in</i> | <i>nx</i> | Size for the first index  |
| <i>in</i> | <i>ny</i> | Size for the second index |

Remarks

The size of resulting vector is nx\*ny

**Vect ( size.t *nx*, size.t *ny*, size.t *nz* )**

Constructor of a 3-D index vector.

This constructor can be used for instance for a 3-D grid vector

Parameters

|           |           |                           |
|-----------|-----------|---------------------------|
| <i>in</i> | <i>nx</i> | Size for the first index  |
| <i>in</i> | <i>ny</i> | Size for the second index |
| <i>in</i> | <i>nz</i> | Size for the third index  |

Remarks

The size of resulting vector is nx\*ny\*nz

**Vect ( size.t *n*, T\_ \* *x* )**

Create an instance of class [Vect](#) as an image of a C/C++ array.

Parameters

|           |          |                                  |
|-----------|----------|----------------------------------|
| <i>in</i> | <i>n</i> | Dimension of vector to construct |
| <i>in</i> | <i>x</i> | C-array to copy                  |

**Vect ( Mesh & *m*, int *nb\_dof* = 0, int *dof\_type* = *NODE\_FIELD* )**

Constructor with a mesh instance.

Parameters

|    |                 |                                                                                                                                                                                                                    |
|----|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                                                                                      |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If <i>nb_dof</i> is set to 0 (default value) the constructor picks this number from the <a href="#">Mesh</a> instance                                       |
| in | <i>dof_type</i> | Type of degrees of freedom. To be given among the enumerated values: <code>NODE_FIELD</code> , <code>ELEMENT_FIELD</code> , <code>SIDE_FIELD</code> or <code>EDGE_FIELD</code> (Default: <code>NODE_FIELD</code> ) |

**Vect ( Mesh & *m*, string *name*, real *t* = 0.0, int *nb\_dof* = 0, int *dof\_type* = `NODE_FIELD` )**

Constructor with a mesh instance giving name and time for vector.

Parameters

|    |                 |                                                                                                                                                                                                                    |
|----|-----------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                                                                                      |
| in | <i>name</i>     | Name of the vector                                                                                                                                                                                                 |
| in | <i>t</i>        | Time value for the vector                                                                                                                                                                                          |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If <i>nb_dof</i> is set to 0 the constructor picks this number from the <a href="#">Mesh</a> instance                                                       |
| in | <i>dof_type</i> | Type of degrees of freedom. To be given among the enumerated values: <code>NODE_FIELD</code> , <code>ELEMENT_FIELD</code> , <code>SIDE_FIELD</code> or <code>EDGE_FIELD</code> (Default: <code>NODE_FIELD</code> ) |

**Vect ( const Element \* *el*, const Vect< T\_ > & *v* )**

Constructor of an element vector.

The constructed vector has local numbering of nodes

Parameters

|    |           |                                                |
|----|-----------|------------------------------------------------|
| in | <i>el</i> | Pointer to <a href="#">Element</a> to localize |
| in | <i>v</i>  | Global vector to localize                      |

**Vect ( const Side \* *sd*, const Vect< T\_ > & *v* )**

Constructor of a side vector.

The constructed vector has local numbering of nodes

Parameters

|    |           |                                             |
|----|-----------|---------------------------------------------|
| in | <i>sd</i> | Pointer to <a href="#">Side</a> to localize |
| in | <i>v</i>  | Global vector to localize                   |

**Vect ( const Vect< T\_ > & *v*, const Vect< T\_ > & *bc* )**

Constructor using boundary conditions.

Boundary condition values contained in *bc* are reported to vector *v*

Parameters

|    |           |                                                                        |
|----|-----------|------------------------------------------------------------------------|
| in | <i>v</i>  | <a href="#">Vect</a> instance to update                                |
| in | <i>bc</i> | <a href="#">Vect</a> instance containing imposed valued at desired DOF |

**Vect ( const Vect< T\_ > & *v*, size\_t *nb\_dof*, size\_t *first\_dof* )**

Constructor to select some components of a given vector.

## Parameters

|    |                  |                                                                                                                                                               |
|----|------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>         | <a href="#">Vect</a> instance to extract from                                                                                                                 |
| in | <i>nb_dof</i>    | Number of DOF to extract                                                                                                                                      |
| in | <i>first_dof</i> | First DOF to extract For instance, a choice <code>first_dof=2</code> and <code>nb_dof=1</code> means that the second DOF of each node is copied in the vector |

**Vect ( const Vect< T\_ > & v, size\_t n )**

Constructor to select one component from a given 2 or 3-component vector.

## Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance to extract from  |
| in | <i>n</i> | Component to extract (must be > 1 and < 4 or). |

**Vect ( size\_t d, const Vect< T\_ > & v, const string & name = " " )**

Constructor that extracts some degrees of freedom (components) from given instance of [Vect](#).

This constructor enables constructing a subvector of a given [Vect](#) instance. It selects a given list of degrees of freedom and put it according to a given order in the instance to construct.

## Parameters

|    |             |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
|----|-------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>d</i>    | Integer number giving the list of degrees of freedom. This number is made of n digits where n is the number of degrees of freedom. Let us give an example: Assume that the instance v has 3 DOF by entity (node, element or side). The choice <code>d=201</code> means that the constructed instance has 2 DOF where the first DOF is the third one of v, and the second DOF is the first one of f v. Consequently, no digit can be larger than the number of DOF the constructed instance. In this example, a choice <code>d=103</code> would produce an error message. |
| in | <i>v</i>    | <a href="#">Vect</a> instance from which extraction is performed.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
| in | <i>name</i> | Name to assign to vector instance (Default value is " ").                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |

## Warning

Don't give zeros as first digits for the argument d. The number is in this case interpreted as octal !!

**Vect ( const VectorX & v )**

Constructor that copies the vector from a Eigen Vector instance.

## Parameters

|    |          |                                                     |
|----|----------|-----------------------------------------------------|
| in | <i>v</i> | VectorX instance from which extraction is performed |
|----|----------|-----------------------------------------------------|

## Warning

This constructor is available only if the library `eigen` is used in conjunction with [OFELI](#)

## Remarks

: This constructor is available only if the Eigen library was installed in conjunction with [OFELI](#)

### 7.108.3 Member Function Documentation

**void set ( const T\_ \* *v*, size\_t *n* )**

Initialize vector with a c-array.



Parameters

|    |          |                                                      |
|----|----------|------------------------------------------------------|
| in | <i>v</i> | c-array (pointer) to initialize <a href="#">Vect</a> |
| in | <i>n</i> | size of array                                        |

**void select ( const Vect< T\_ > &v, size\_t nb\_dof = 0, size\_t first\_dof = 1 )**

Initialize vector with another [Vect](#) instance.

Parameters

|    |                  |                                                                                                                                                  |
|----|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>         | <a href="#">Vect</a> instance to extract from                                                                                                    |
| in | <i>nb_dof</i>    | Number of DOF per node, element or side (By default, 0: Number of degrees of freedom extracted from the <a href="#">Mesh</a> instance)           |
| in | <i>first_dof</i> | First DOF to extract (Default: 1) For instance, a choice first_dof=2 and nb_dof=1 means that the second DOF of each node is copied in the vector |

**void set ( const string &exp, size\_t dof = 1 )**

Initialize vector with an algebraic expression.

This function is to be used is a [Mesh](#) instance is associated to the vector

Parameters

|    |            |                                                                                                                               |
|----|------------|-------------------------------------------------------------------------------------------------------------------------------|
| in | <i>exp</i> | Regular algebraic expression that defines a function of x, y, z which are coordinates of nodes and t which is the time value. |
| in | <i>dof</i> | Degree of freedom to which the value is assigned [Default: 1]                                                                 |

Warning

If the time variable t is involved in the expression, the time value associated to the vector instance must be defined (Default value is 0) either by using the appropriate constructor or by the member function setTime.

**void set ( const string &exp, const Vect< real.t > &x )**

Initialize vector with an algebraic expression.

This function can be used for instance in 1-D

Parameters

|    |            |                                                                                          |
|----|------------|------------------------------------------------------------------------------------------|
| in | <i>exp</i> | Regular algebraic expression that defines a function of x which are coordinates of nodes |
| in | <i>x</i>   | Vector                                                                                   |

**void set ( const Mesh &ms, const string &exp, size\_t dof = 1 )**

Initialize vector with an algebraic expression with providing mesh data.

Parameters

|    |           |                               |
|----|-----------|-------------------------------|
| in | <i>ms</i> | <a href="#">Mesh</a> instance |
|----|-----------|-------------------------------|

|    |            |                                                                                                    |
|----|------------|----------------------------------------------------------------------------------------------------|
| in | <i>exp</i> | Regular algebraic expression that defines a function of x, y and z which are coordinates of nodes. |
| in | <i>dof</i> | Degree of freedom to which the value is assigned [Default: 1]                                      |

**void set ( const Vect< real\_t > & x, const string & exp )**

Initialize vector with an algebraic expression.

Parameters

|    |            |                                                                                                                             |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------|
| in | <i>x</i>   | <a href="#">Vect</a> instance that contains coordinates of points                                                           |
| in | <i>exp</i> | Regular algebraic expression that defines a function of x and i which are coordinates of nodes and indices starting from 1. |

**void setMesh ( Mesh & m, size\_t nb\_dof = 0, size\_t dof\_type = NODE\_FIELD )**

Define mesh class to size vector.

Parameters

|    |                 |                                                                                                                                                                        |
|----|-----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>        | <a href="#">Mesh</a> instance                                                                                                                                          |
| in | <i>nb_dof</i>   | Number of degrees of freedom per node, element or side If nb_dof is set to 0 the constructor picks this number from the <a href="#">Mesh</a> instance                  |
| in | <i>dof_type</i> | Parameter to precise the type of degrees of freedom. To be chosen among the enumerated values: NODE_FIELD, ELEMENT_FIELD, SIDE_FIELD, EDGE_FIELD [Default: NODE_FIELD] |

**size\_t size ( ) const**

Return vector (global) size.

Warning

This constructor is available only if the library `eigen` is used in conjunction with [OFELI](#)

**void setSize ( size\_t nx, size\_t ny = 1, size\_t nz = 1 )**

Set vector size (for 1-D, 2-D or 3-D cases)

This function allocates memory for the vector but does not initialize its components

Parameters

|    |           |                                                   |
|----|-----------|---------------------------------------------------|
| in | <i>nx</i> | Number of grid points in x-direction              |
| in | <i>ny</i> | Number of grid points in y-direction [Default: 1] |
| in | <i>nz</i> | Number of grid points in z-direction [Default: 1] |

**void resize ( size\_t n )**

Set vector size.

This function allocates memory for the vector but does not initialize its components

Parameters

|                 |                |                |
|-----------------|----------------|----------------|
| <code>in</code> | <code>n</code> | Size of vector |
|-----------------|----------------|----------------|

**void resize ( `size_t n`, `T_ v` )**

Set vector size and initialize to a constant value.

This function allocates memory for the vector

Parameters

|                 |                |                                   |
|-----------------|----------------|-----------------------------------|
| <code>in</code> | <code>n</code> | Size of vector                    |
| <code>in</code> | <code>v</code> | Value to assign to vector entries |

**void setDOFType ( `int dof_type` )**

Set DOF type of vector.

The DOF type combined with number of DOF per component enable determining the size of vector

Parameters

|                 |                       |                                                                                                                                                                                       |
|-----------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <code>in</code> | <code>dof_type</code> | Type of degrees of freedom. Value to be chosen among the enumerated values: <code>NODE_FIELD</code> , <code>ELEMENT_FIELD</code> , <code>SIDE_FIELD</code> or <code>EDGE_FIELD</code> |
|-----------------|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void setDG ( `int degree = 1` )**

Set Discontinuous Galerkin type vector.

When the vector is associated to a mesh, this one is sized differently if the DG method is used.

Parameters

|                 |                     |                                                 |
|-----------------|---------------------|-------------------------------------------------|
| <code>in</code> | <code>degree</code> | Polynomial degree of the DG method [Default: 1] |
|-----------------|---------------------|-------------------------------------------------|

**bool WithMesh ( ) const**

Return true if vector contains a [Mesh](#) pointer, false if not.

A [Vect](#) instance can be constructed using mesh information

**int getDOFType ( ) const**

Return DOF type of vector

Returns

`dof_type` Type of degrees of freedom. Value among the enumerated values: `NODE_FIELD`, `ELEMENT_FIELD`, `SIDE_FIELD` or `EDGE_FIELD`

**real\_t getNorm1 ( ) const**

Calculate 1-norm of vector.

Remarks

This function is available only if the template parameter is `double` or `complex<double>`

**real\_t getNorm2 ( ) const**

Calculate 2-norm (Euclidean norm) of vector.

Remarks

This function is available only if the template parameter is `double` or `complex<double>`

**real\_t getNormMax ( ) const**

Calculate Max-norm (Infinite norm) of vector.

Remarks

This function is available only if the template parameter is `double` or `complex<double>`

**real\_t getWNorm2 ( ) const**

Calculate weighted 2-norm of vector.

The weighted 2-norm is the 2-Norm of the vector divided by the square root of its size

**void setNodeBC ( Mesh & m, int code, T\_ val, size\_t dof = 1 )**

Assign a given value to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>m</i>    | Instance of mesh                                               |
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>val</i>  | Value to prescribe                                             |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |

**void setNodeBC ( Mesh & m, int code, const string & exp, size\_t dof = 1 )**

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>m</i>    | Instance of mesh                                               |
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>exp</i>  | Regular algebraic expression to prescribe                      |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |

**void setNodeBC ( int code, T\_ val, size\_t dof = 1 )**

Assign a given value to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>val</i>  | Value to prescribe                                             |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |

**void setNodeBC ( int *code*, const string & *exp*, size\_t *dof* = 1 )**

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

|    |             |                                                                |
|----|-------------|----------------------------------------------------------------|
| in | <i>code</i> | Code for which nodes will be assigned prescribed value         |
| in | <i>exp</i>  | Regular algebraic expression to prescribe                      |
| in | <i>dof</i>  | Degree of Freedom for which the value is assigned [default: 1] |

**void removeBC ( const Mesh & *ms*, const Vect< T\_ > & *v*, int *dof* = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>ms</i>  | <a href="#">Mesh</a> instance                                                                                                                                                                |
| in | <i>v</i>   | Vector ( <a href="#">Vect</a> instance to copy from)                                                                                                                                         |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom |

**void removeBC ( const Vect< T\_ > & *v*, int *dof* = 0 )**

Remove boundary conditions.

This member function copies to current vector a vector where only non imposed DOF are retained.

Parameters

|    |            |                                                                                                                                                                                              |
|----|------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | Vector ( <a href="#">Vect</a> instance to copy from)                                                                                                                                         |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned [Default: 0] or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom. |

Remarks

This function is to be used only when the [Vect](#) instance was constructed by using the [Mesh](#) instance

**void transferBC ( const Vect< T\_ > & *bc*, int *dof* = 0 )**

Transfer boundary conditions to the vector.

Parameters

|    |            |                                                                                                                                                                                               |
|----|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>bc</i>  | <a href="#">Vect</a> instance from which imposed degrees of freedom are copied to current instance                                                                                            |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom. |

**void insertBC ( Mesh & *m*, const Vect< T\_ > & *v*, const Vect< T\_ > & *bc*, int *dof* = 0 )**

Insert boundary conditions.

Parameters

|    |            |                                                                                                                                                                                                              |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>   | <a href="#">Mesh</a> instance.                                                                                                                                                                               |
| in | <i>v</i>   | <a href="#">Vect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                             |
| in | <i>bc</i>  | <a href="#">Vect</a> instance from which imposed degrees of freedom are copied to current instance.                                                                                                          |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( Mesh & *m*, const Vect< T\_ > & *v*, int *dof* = 0 )**

Insert boundary conditions.

DOF with imposed boundary conditions are set to zero.

Parameters

|    |            |                                                                                                                                                                                                              |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>m</i>   | <a href="#">Mesh</a> instance.                                                                                                                                                                               |
| in | <i>v</i>   | <a href="#">Vect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                             |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( const Vect< T\_ > & *v*, const Vect< T\_ > & *bc*, int *dof* = 0 )**

Insert boundary conditions.

Parameters

|    |            |                                                                                                                                                                                                              |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | <a href="#">Vect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                             |
| in | <i>bc</i>  | <a href="#">Vect</a> instance from which imposed degrees of freedom are copied to current instance.                                                                                                          |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void insertBC ( const Vect< T\_ > & *v*, int *dof* = 0 )**

Insert boundary conditions.

DOF with imposed boundary conditions are set to zero.

Parameters

|    |            |                                                                                                                                                                                                              |
|----|------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i>   | <a href="#">Vect</a> instance from which free degrees of freedom are copied to current instance.                                                                                                             |
| in | <i>dof</i> | Parameter to say if all degrees of freedom are concerned (=0, Default) or if only one degree of freedom ( <i>dof</i> ) is inserted into vector <i>v</i> which has only one degree of freedom by node or side |

**void Assembly ( const Element & *el*, const Vect< T\_ > & *b* )**

Assembly of element vector into current instance.

Parameters

|    |           |                                                                    |
|----|-----------|--------------------------------------------------------------------|
| in | <i>el</i> | Reference to <a href="#">Element</a> instance                      |
| in | <i>b</i>  | Local vector to assemble (Instance of class <a href="#">Vect</a> ) |

**void Assembly ( const Element & *el*, const T\_ \* *b* )**

Assembly of element vector (as C-array) into [Vect](#) instance.

Parameters

|    |           |                                               |
|----|-----------|-----------------------------------------------|
| in | <i>el</i> | Reference to <a href="#">Element</a> instance |
| in | <i>b</i>  | Local vector to assemble (C-Array)            |

**void Assembly ( const Side & *sd*, const Vect< T\_ > & *b* )**

Assembly of side vector into [Vect](#) instance.

Parameters

|    |           |                                                                    |
|----|-----------|--------------------------------------------------------------------|
| in | <i>sd</i> | Reference to <a href="#">Side</a> instance                         |
| in | <i>b</i>  | Local vector to assemble (Instance of class <a href="#">Vect</a> ) |

**void Assembly ( const Side & *sd*, T\_ \* *b* )**

Assembly of side vector (as C-array) into [Vect](#) instance.

Parameters

|    |           |                                            |
|----|-----------|--------------------------------------------|
| in | <i>sd</i> | Reference to <a href="#">Side</a> instance |
| in | <i>b</i>  | Local vector to assemble (C-Array)         |

**void getGradient ( class Vect< T\_ > & *v* )**

Evaluate the discrete Gradient vector of the current vector.

The resulting gradient is stored in a [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The gradient is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                               |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the gradient, where $v(n,1)$ , $v(n,2)$ and $v(n,3)$ are respectively the x and y and z derivatives at element n. |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getGradient ( Vect< Point< T\_ > > & *v* )**

Evaluate the discrete Gradient vector of the current vector.

The resulting gradient is stored in an [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The gradient is then a constant vector for each element.

Parameters

|    |          |                                                                                                                                                                                       |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance that contains the gradient, where $v(n,1) \cdot x$ , $v(n,2) \cdot y$ and $v(n,3) \cdot z$ are respectively the x and y and z derivatives at element n. |
|----|----------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|



**void getCurl ( Vect< T\_ > & v )**

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The curl is then a constant vector for each element.

Parameters

|    |   |                                                                                                                                                               |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | v | <a href="#">Vect</a> instance that contains the curl, where $v(n,1)$ , $v(n,2)$ and $v(n,3)$ are respectively the x and y and z curl components at element n. |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getCurl ( Vect< Point< T\_ > > & v )**

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The curl is then a constant vector for each element.

Parameters

|    |   |                                                                                                                                                                     |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | v | <a href="#">Vect</a> instance that contains the curl, where $v(n,1).x$ , $v(n,2).y$ and $v(n,3).z$ are respectively the x and y and z curl components at element n. |
|----|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**void getSCurl ( Vect< T\_ > & v )**

Evaluate the discrete scalar curl in 2-D of the current vector.

The resulting curl is stored in a [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The curl is then a constant vector for each element.

Parameters

|    |   |                                                              |
|----|---|--------------------------------------------------------------|
| in | v | <a href="#">Vect</a> instance that contains the scalar curl. |
|----|---|--------------------------------------------------------------|

**void getDivergence ( Vect< T\_ > & v )**

Evaluate the discrete Divergence of the current vector.

The resulting divergence is stored in a [Vect](#) instance. This function handles node vectors assuming  $P_1$  approximation. The divergence is then a constant vector for each element.

Parameters

|    |   |                                                             |
|----|---|-------------------------------------------------------------|
| in | v | <a href="#">Vect</a> instance that contains the divergence. |
|----|---|-------------------------------------------------------------|

**real.t getAverage ( const Element & el, int type ) const**

Return average value of vector in a given element.

Parameters

|    |      |                                                                                                             |
|----|------|-------------------------------------------------------------------------------------------------------------|
| in | el   | <a href="#">Element</a> instance                                                                            |
| in | type | Type of element. This is to be chosen among enumerated values: LINE2, TRIANG3, QUAD4, TETRA4, HEXA8, PENTA6 |

**void save ( string file, int opt )**

Save vector in a file according to a given format.

Parameters

|    |             |                                                                                                                            |
|----|-------------|----------------------------------------------------------------------------------------------------------------------------|
| in | <i>file</i> | Output file where to save the vector                                                                                       |
| in | <i>opt</i>  | Option to choose file format to save. This is to be chosen among enumerated values: GMSH, GNUPLOT, MATLAB, TECPLOT and VTK |

**Vect<T\_>& MultAdd ( const Vect< T\_ > & *x*, const T\_ & *a* )**

Multiply by a constant then add to a vector.

Parameters

|    |          |                                      |
|----|----------|--------------------------------------|
| in | <i>x</i> | <a href="#">Vect</a> instance to add |
| in | <i>a</i> | Constant to multiply before adding   |

**void Axy ( T\_ *a*, const Vect< T\_ > & *x* )**

Add to vector the product of a vector by a scalar.

Parameters

|    |          |                                                                                                        |
|----|----------|--------------------------------------------------------------------------------------------------------|
| in | <i>a</i> | Scalar to premultiply                                                                                  |
| in | <i>x</i> | <a href="#">Vect</a> instance by which <i>a</i> is multiplied. The result is added to current instance |

**void set ( size\_t *i*, T\_ *val* )**

Assign a value to an entry for a 1-D vector.

Parameters

|    |            |                                    |
|----|------------|------------------------------------|
| in | <i>i</i>   | Rank index in vector (starts at 1) |
| in | <i>val</i> | Value to assign                    |

**void set ( size\_t *i*, size\_t *j*, T\_ *val* )**

Assign a value to an entry for a 2-D vector.

Parameters

|    |            |                                      |
|----|------------|--------------------------------------|
| in | <i>i</i>   | First index in vector (starts at 1)  |
| in | <i>j</i>   | Second index in vector (starts at 1) |
| in | <i>val</i> | Value to assign                      |

**void set ( size\_t *i*, size\_t *j*, size\_t *k*, T\_ *val* )**

Assign a value to an entry for a 3-D vector.

Parameters

|    |          |                                      |
|----|----------|--------------------------------------|
| in | <i>i</i> | First index in vector (starts at 1)  |
| in | <i>j</i> | Second index in vector (starts at 1) |
| in | <i>k</i> | Third index in vector (starts at 1)  |

|           |            |                 |
|-----------|------------|-----------------|
| <b>in</b> | <i>val</i> | Value to assign |
|-----------|------------|-----------------|

**void add ( size\_t *i*, T\_ *val* )**

Add a value to an entry for a 1-index vector.

Parameters

|           |            |                                    |
|-----------|------------|------------------------------------|
| <b>in</b> | <i>i</i>   | Rank index in vector (starts at 1) |
| <b>in</b> | <i>val</i> | Value to assign                    |

**void add ( size\_t *i*, size\_t *j*, T\_ *val* )**

Add a value to an entry for a 2-index vector.

Parameters

|           |            |                                      |
|-----------|------------|--------------------------------------|
| <b>in</b> | <i>i</i>   | First index in vector (starts at 1)  |
| <b>in</b> | <i>j</i>   | Second index in vector (starts at 1) |
| <b>in</b> | <i>val</i> | Value to assign                      |

**void add ( size\_t *i*, size\_t *j*, size\_t *k*, T\_ *val* )**

Assign a value to an entry for a 3-index vector.

Parameters

|           |            |                                      |
|-----------|------------|--------------------------------------|
| <b>in</b> | <i>i</i>   | First index in vector (starts at 1)  |
| <b>in</b> | <i>j</i>   | Second index in vector (starts at 1) |
| <b>in</b> | <i>k</i>   | Third index in vector (starts at 1)  |
| <b>in</b> | <i>val</i> | Value to assign                      |

**T\_& operator[] ( size\_t *i* )**

Operator [] (Non constant version)

Parameters

|           |          |                                    |
|-----------|----------|------------------------------------|
| <b>in</b> | <i>i</i> | Rank index in vector (starts at 0) |
|-----------|----------|------------------------------------|

**T\_ operator[] ( size\_t *i* ) const**

Operator [] (Constant version)

Parameters

|           |          |                                    |
|-----------|----------|------------------------------------|
| <b>in</b> | <i>i</i> | Rank index in vector (starts at 0) |
|-----------|----------|------------------------------------|

**T\_& operator() ( size\_t *i* )**

Operator () (Non constant version)

Parameters

|    |          |                                                                                                                                                                                                                                        |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | Rank index in vector (starts at 1) <ul style="list-style-type: none"> <li>• <code>v(i)</code> starts at <code>v(1)</code> to <code>v(size())</code></li> <li>• <code>v(i)</code> is the same element as <code>v[i-1]</code></li> </ul> |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**T\_ operator() ( size\_t *i* ) const**

Operator () (Constant version)

Parameters

|    |          |                                                                                                                                                                                                                                        |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | Rank index in vector (starts at 1) <ul style="list-style-type: none"> <li>• <code>v(i)</code> starts at <code>v(1)</code> to <code>v(size())</code></li> <li>• <code>v(i)</code> is the same element as <code>v[i-1]</code></li> </ul> |
|----|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|

**T\_& operator() ( size\_t *i*, size\_t *j* )**

Operator () with 2-D indexing (Non constant version, case of a grid vector).

Parameters

|    |          |                                                                                                                                                           |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | first index in vector (Number of vector components in the x-grid)                                                                                         |
| in | <i>j</i> | second index in vector (Number of vector components in the y-grid) <code>v(i, j)</code> starts at <code>v(1,1)</code> to <code>v(getNx(), getNy())</code> |

**T\_ operator() ( size\_t *i*, size\_t *j* ) const**

Operator () with 2-D indexing (Constant version).

Parameters

|    |          |                                                                                                                                                           |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | first index in vector (Number of vector components in the x-grid)                                                                                         |
| in | <i>j</i> | second index in vector (Number of vector components in the y-grid) <code>v(i, j)</code> starts at <code>v(1,1)</code> to <code>v(getNx(), getNy())</code> |

**T\_& operator() ( size\_t *i*, size\_t *j*, size\_t *k* )**

Operator () with 3-D indexing (Non constant version).

Parameters

|    |          |                                                                                                                                                                        |
|----|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | first index in vector (Number of vector components in the x-grid)                                                                                                      |
| in | <i>j</i> | second index in vector (Number of vector components in the y-grid)                                                                                                     |
| in | <i>k</i> | third index in vector (Number of vector components in the z-grid) <code>v(i, j, k)</code> starts at <code>v(1,1,1)</code> to <code>v(getNx(), getNy(), getNz())</code> |

**T\_ operator() ( size\_t *i*, size\_t *j*, size\_t *k* ) const**

Operator () with 3-D indexing (Constant version).

Parameters

|    |          |                                                                                                                                                                                                                 |
|----|----------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| in | <i>i</i> | first index in vector (Number of vector components in the x-grid)                                                                                                                                               |
| in | <i>j</i> | second index in vector (Number of vector components in the y-grid)                                                                                                                                              |
| in | <i>k</i> | third index in vector (Number of vector components in the z-grid)<br>v( <i>i</i> , <i>j</i> , <i>k</i> ) starts at v(1,1,1) to v( <a href="#">getNx()</a> , <a href="#">getNy()</a> , <a href="#">getNz()</a> ) |

**Vect<T\_>& operator= ( const VectorX & v )**

Operator = for an instance of VectorX

Parameters

|    |          |                                           |
|----|----------|-------------------------------------------|
| in | <i>v</i> | Instance of vector class in library Eigen |
|----|----------|-------------------------------------------|

Remarks

The [Vect](#) instance must have been sized beforeThis operator is available only if the Eigen library was installed in conjunction with [OFELI](#)**void operator= ( string s )**

Operator =

Assign an algebraic expression to vector entries. This operator has the same effect as the member function set(s)

Parameters

|    |          |                                                                                |
|----|----------|--------------------------------------------------------------------------------|
| in | <i>s</i> | String defining the algebraic expression as a function of coordinates and time |
|----|----------|--------------------------------------------------------------------------------|

Warning

A [Mesh](#) instance must has been introduced before (*e.g.* by a constructor)**void setUniform ( T\_ vmin, T\_ delta, T\_ vmax )**

Initialize vector entries by setting extremal values and interval.

Parameters

|    |              |                                            |
|----|--------------|--------------------------------------------|
| in | <i>vmin</i>  | Minimal value to assign to the first entry |
| in | <i>delta</i> | Interval                                   |
| in | <i>vmax</i>  | Maximal value to assign to the lase entry  |

Remarks

Vector's size is deduced from the arguments. The vector does not need to be sized before using this function

**Vect<T\_>& operator= ( const T\_ & a )**

Operator =

Assign a constant to vector entries

Parameters

|    |          |              |
|----|----------|--------------|
| in | <i>a</i> | Value to set |
|----|----------|--------------|

**Vect<T\_>& operator+= ( const Vect< T\_ > & *v* )**

Operator +=

Add vector *x* to current vector instance.

Parameters

|    |          |                                                  |
|----|----------|--------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance to add to instance |
|----|----------|--------------------------------------------------|

**Vect<T\_>& operator+= ( const T\_ & *a* )**

Operator +=

Add a constant to current vector entries.

Parameters

|    |          |                                |
|----|----------|--------------------------------|
| in | <i>a</i> | Value to add to vector entries |
|----|----------|--------------------------------|

**Vect<T\_>& operator-= ( const Vect< T\_ > & *v* )**

Operator -=

Parameters

|    |          |                                                |
|----|----------|------------------------------------------------|
| in | <i>v</i> | <a href="#">Vect</a> instance to subtract from |
|----|----------|------------------------------------------------|

**Vect<T\_>& operator-= ( const T\_ & *a* )**

Operator -=

Subtract constant from vector entries.

Parameters

|    |          |                        |
|----|----------|------------------------|
| in | <i>a</i> | Value to subtract from |
|----|----------|------------------------|

**Vect<T\_>& operator\*= ( const T\_ & *a* )**

Operator \*=

Parameters

|    |          |                      |
|----|----------|----------------------|
| in | <i>a</i> | Value to multiply by |
|----|----------|----------------------|

**Vect<T\_>& operator/= ( const T\_ & *a* )**

Operator /=

Parameters

|    |          |                    |
|----|----------|--------------------|
| in | <i>a</i> | Value to divide by |
|----|----------|--------------------|

**void push.back ( const T\_ & v )**

Add an entry to the vector.

This function is an overload of the member function push.back of the parent class vector. It adjusts in addition some vector parameters

Parameters

|                 |                |                    |
|-----------------|----------------|--------------------|
| <code>in</code> | <code>v</code> | Entry value to add |
|-----------------|----------------|--------------------|

**T\_ operator, ( const Vect< T\_ > & v ) const**

Return Dot (scalar) product of two vectors.

A typical use of this operator is `double a = (v,w)` where `v` and `w` are 2 instances of `Vect<double>`

Parameters

|                 |                |                                                                           |
|-----------------|----------------|---------------------------------------------------------------------------|
| <code>in</code> | <code>v</code> | <a href="#">Vect</a> instance by which the current instance is multiplied |
|-----------------|----------------|---------------------------------------------------------------------------|

**operator VectorX ( ) const**

Casting operator.

Warning

This constructor is available only if the library `eigen` is used in conjunction with [OFELI](#)



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