



**An Object Oriented Finite Element Library**

**Reference Guide**

Release 3.2.0

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# Chapter 1

## Module Index

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Here is a list of all modules:

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## Chapter 2

# Namespace Index

## 2.1 Namespace List

Here is a list of all documented namespaces with brief descriptions:

OFELI	
A namespace to group all library classes, functions, ..	159



## Chapter 3

# Hierarchical Index

### 3.1 Class Hierarchy

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

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Equation< complex_t, NEN_, NEE_, NSN_, NSE_ > . . . . .	613
Equa_Electromagnetics< complex_t, 3, 3, 2, 2 > . . . . .	517
EC2D1T3 . . . . .	388
HelmholtzBT3 . . . . .	647
AbsEqua< double > . . . . .	179
Equation< double, NEN_, NEE_, NSN_, NSE_ > . . . . .	613
Equa_Solid< double, 8, 24, 4, 12 > . . . . .	578
Elas3DH8 . . . . .	470
AbsEqua< real_t > . . . . .	179
Equation< real_t, NEN_, NEE_, NSN_, NSE_ > . . . . .	613
Equa_Electromagnetics< real_t, 3, 6, 2, 4 > . . . . .	517
EC2D2T3 . . . . .	404
Equa_Fluid< real_t, 3, 6, 2, 4 > . . . . .	531
TINS2DT3S . . . . .	1057
Equa_Fluid< real_t, 4, 12, 3, 9 > . . . . .	531
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Equa_Solid< real_t, 2, 12, 1, 1 > . . . . .	578
Beam3DL2 . . . . .	200

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Equa.Solid< real.t, 3, 6, 2, 4 > . . . . .	578
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DC3DT4 . . . . .	326
Equa.Therm< real.t, 6, 6, 3, 3 > . . . . .	595
DC2DT6 . . . . .	284
LocalMatrix< complex.t, NEE_, NEE_ > . . . . .	814
LocalMatrix< complex.t, NSE_, NSE_ > . . . . .	814
LocalMatrix< double, NEE_, NEE_ > . . . . .	814
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LocalMatrix< real.t, NEE_, NEE_ > . . . . .	814
LocalMatrix< real.t, NSE_, NSE_ > . . . . .	814
LocalMatrix< T_, NEE_, NEE_ > . . . . .	814
LocalMatrix< T_, NSE_, NSE_ > . . . . .	814
LocalVect< complex.t, NEE_ > . . . . .	816
LocalVect< complex.t, NSE_ > . . . . .	816
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# Chapter 4

## Class Index

### 4.1 Class List

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

<a href="#">AbsEqua&lt; T_ &gt;</a>	Mother abstract class to describe equation . . . . .	179
<a href="#">Bar2DL2</a>	To build element equations for Planar Elastic Bar element with 2 DOF (Degrees of Freedom) per node . . . . .	181
<a href="#">Beam3DL2</a>	To build element equations for 3-D beam equations using 2-node lines . . . . .	200
<a href="#">BiotSavart</a>	Class to compute the magnetic induction from the current density using the Biot-Savart formula . . . . .	217
<a href="#">BMatrix&lt; T_ &gt;</a>	To handle band matrices . . . . .	222
<a href="#">Brick</a>	To store and treat a brick (parallelepiped) figure . . . . .	232
<a href="#">Circle</a>	To store and treat a circular figure . . . . .	235
<a href="#">DC1DL2</a>	Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements . . . . .	237
<a href="#">DC2DT3</a>	Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles . . . . .	259
<a href="#">DC2DT6</a>	Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles . . . . .	284
<a href="#">DC3DAT3</a>	Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles . . . . .	304
<a href="#">DC3DT4</a>	Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra . . . . .	326
<a href="#">DG</a>	Enables preliminary operations and utilities for the Discontinuous Galerkin method . . . . .	349

<a href="#">DMatrix&lt; T_ &gt;</a>	To handle dense matrices . . . . .	351
<a href="#">Domain</a>	To store and treat finite element geometric information . . . . .	369
<a href="#">DSMatrix&lt; T_ &gt;</a>	To handle symmetric dense matrices . . . . .	374
<a href="#">EC2D1T3</a>	Eddy current problems in 2-D domains using solenoidal approximation . . . .	388
<a href="#">EC2D2T3</a>	Eddy current problems in 2-D domains using transversal approximation . . .	404
<a href="#">Edge</a>	To describe an edge . . . . .	419
<a href="#">EdgeList</a>	Class to construct a list of edges having some common properties . . . . .	422
<a href="#">EigenProblemSolver</a>	Class to find eigenvalues and corresponding eigenvectors of a given matrix in a generalized eigenproblem, <i>i.e.</i> 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 <i>Stiffness</i> and <i>Mass</i> matrices respectively . . . . .	423
<a href="#">Elas2DQ4</a>	To build element equations for 2-D linearized elasticity using 4-node quadrilaterals . . . . .	429
<a href="#">Elas2DT3</a>	To build element equations for 2-D linearized elasticity using 3-node triangles	448
<a href="#">Elas3DH8</a>	To build element equations for 3-D linearized elasticity using 8-node hexahedra	470
<a href="#">Elas3DT4</a>	To build element equations for 3-D linearized elasticity using 4-node tetrahedra	487
<a href="#">Element</a>	To store and treat finite element geometric information . . . . .	504
<a href="#">ElementList</a>	Class to construct a list of elements having some common properties . . . . .	513
<a href="#">Ellipse</a>	To store and treat an ellipsoidal figure . . . . .	514
<a href="#">Equa_Electromagnetics&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for Electromagnetics <a href="#">Equation</a> classes . . . . .	517
<a href="#">Equa_Fluid&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for Fluid Dynamics <a href="#">Equation</a> classes . . . . .	531
<a href="#">Equa_Laplace&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for classes about the Laplace equation . . . . .	546
<a href="#">Equa_Porous&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for Porous Media Finite Element classes . . . . .	562
<a href="#">Equa_Solid&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for Solid Mechanics Finite Element classes . . . . .	578
<a href="#">Equa_Therm&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for Heat transfer Finite Element classes . . . . .	595
<a href="#">Equation&lt; T_, NEN_, NEE_, NSN_, NSE_ &gt;</a>	Abstract class for all equation classes . . . . .	613
<a href="#">Estimator</a>	To calculate an a posteriori estimator of the solution . . . . .	628
<a href="#">FastMarching2D</a>	To run a Fast Marching Method on 2-D structured uniform grids . . . . .	630

<a href="#">FEShape</a>	Parent class from which inherit all finite element shape classes . . . . .	632
<a href="#">Figure</a>	To store and treat a figure (or shape) information . . . . .	634
<a href="#">FMM2D</a>	Class for the fast marching 2-D algorithm . . . . .	636
<a href="#">FMM3D</a>	Class for the 3-D fast marching algorithm . . . . .	638
<a href="#">FMMSolver</a>	The Fast Marching Method solver . . . . .	640
<a href="#">Funct</a>	A simple class to parse real valued functions . . . . .	641
<a href="#">Gauss</a>	Calculate data for Gauss integration . . . . .	643
<a href="#">Grid</a>	To manipulate structured grids . . . . .	644
<a href="#">HelmholtzBT3</a>	Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles . . . . .	647
<a href="#">Hexa8</a>	Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation . . . . .	661
<a href="#">ICPG1D</a>	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D . . . . .	664
<a href="#">ICPG2DT</a>	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D . . . . .	672
<a href="#">ICPG3DT</a>	Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D . . . . .	679
<a href="#">IOField</a>	Enables working with files in the XML Format . . . . .	684
<a href="#">IPF</a>	To read project parameters from a file in <a href="#">IPF</a> format . . . . .	685
<a href="#">Iter&lt; T_&gt;</a>	Class to drive an iterative process . . . . .	695
<a href="#">Laplace1DL2</a>	To build element equation for a 1-D elliptic equation using the 2-Node line element ( $P_1$ ) . . . . .	696
<a href="#">Laplace1DL3</a>	To build element equation for the 1-D elliptic equation using the 3-Node line ( $P_2$ ) . . . . .	713
<a href="#">Laplace2DFVT</a>	To build and solve the Laplace equation using a standard Finite Volume method . . . . .	729
<a href="#">Laplace2DMHRT0</a>	To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas $RT_0$ ) . . . . .	746
<a href="#">Laplace2DT3</a>	To build element equation for the Laplace equation using the 2-D triangle element ( $P_1$ ) . . . . .	763
<a href="#">LaplaceDG2DP1</a>	To build and solve the linear system for the Poisson problem using the <a href="#">DG</a> $P_1$ 2-D triangle element . . . . .	781

<a href="#">LCL1D</a>	Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme . . . . .	783
<a href="#">LCL2DT</a>	Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles . . . . .	789
<a href="#">LCL3DT</a>	Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra . . . . .	794
<a href="#">Line2</a>	To describe a 2-Node planar line finite element . . . . .	800
<a href="#">Line2H</a>	To describe a 2-Node Hermite planar line finite element . . . . .	803
<a href="#">Line3</a>	To describe a 3-Node quadratic planar line finite element . . . . .	805
<a href="#">LinearSolver&lt; T_ &gt;</a>	Class to solve systems of linear equations by iterative methods . . . . .	807
<a href="#">LocalMatrix&lt; T_, NR_, NC_ &gt;</a>	Handles small size matrices like element matrices, with a priori known size . .	814
<a href="#">LocalVect&lt; T_, N_ &gt;</a>	Handles small size vectors like element vectors . . . . .	816
<a href="#">Material</a>	To treat material data. This class enables reading material data in material data files. It also returns these informations by means of its members . . . . .	819
<a href="#">Matrix&lt; T_ &gt;</a>	Virtual class to handle matrices for all storage formats . . . . .	822
<a href="#">Mesh</a>	To store and manipulate finite element meshes . . . . .	831
<a href="#">MeshAdapt</a>	To adapt mesh in function of given solution . . . . .	853
<a href="#">Muscl</a>	Parent class for hyperbolic solvers with Muscl scheme . . . . .	858
<a href="#">Muscl1D</a>	Class for 1-D hyperbolic solvers with <a href="#">Muscl</a> scheme . . . . .	861
<a href="#">Muscl2DT</a>	Class for 2-D hyperbolic solvers with <a href="#">Muscl</a> scheme . . . . .	865
<a href="#">Muscl3DT</a>	Class for 3-D hyperbolic solvers with <a href="#">Muscl</a> scheme using tetrahedra . . . . .	869
<a href="#">MyNLAS</a>	Abstract class to define by user specified function . . . . .	873
<a href="#">MyOpt</a>	Abstract class to define by user specified optimization function . . . . .	874
<a href="#">NLASSolver</a>	To solve a system of nonlinear algebraic equations of the form $f(u) = 0$ . . . . .	875
<a href="#">Node</a>	To describe a node . . . . .	881
<a href="#">NodeList</a>	Class to construct a list of nodes having some common properties . . . . .	885
<a href="#">NSP2DQ41</a>	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 . . . . .	887
<a href="#">ODESolver</a>	To solve a system of ordinary differential equations . . . . .	903

<a href="#">OFELIException</a>	To handle exceptions in <a href="#">OFELI</a> . . . . .	913
<a href="#">OptSolver</a>	To solve an optimization problem with bound constraints . . . . .	913
<a href="#">Partition</a>	To partition a finite element mesh into balanced submeshes . . . . .	921
<a href="#">Penta6</a>	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 $(s.y, s.z)$ . . . . .	925
<a href="#">PETScMatrix&lt; T_ &gt;</a>	To handle matrices in sparse storage format using the Petsc library . . . . .	927
<a href="#">PETScVect&lt; T_ &gt;</a>	To handle general purpose vectors using Petsc . . . . .	939
<a href="#">PETScWrapper&lt; T_ &gt;</a>	This class is a wrapper to be used when the library Petsc is installed and used with <a href="#">OFELI</a> . . . . .	960
<a href="#">PhaseChange</a>	This class enables defining phase change laws for a given material . . . . .	968
<a href="#">Point&lt; T_ &gt;</a>	Defines a point with arbitrary type coordinates . . . . .	969
<a href="#">Point2D&lt; T_ &gt;</a>	Defines a 2-D point with arbitrary type coordinates . . . . .	972
<a href="#">Polygon</a>	To store and treat a polygonal figure . . . . .	975
<a href="#">Prec&lt; T_ &gt;</a>	To set a preconditioner . . . . .	978
<a href="#">Prescription</a>	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 . . . . .	981
<a href="#">Quad4</a>	Defines a 4-node quadrilateral finite element using $Q_1$ isoparametric interpolation . . . . .	983
<a href="#">Reconstruction</a>	To perform various reconstruction operations . . . . .	986
<a href="#">Rectangle</a>	To store and treat a rectangular figure . . . . .	987
<a href="#">Side</a>	To store and treat finite element sides (edges in 2-D or faces in 3-D) . . . . .	989
<a href="#">SideList</a>	Class to construct a list of sides having some common properties . . . . .	995
<a href="#">SkMatrix&lt; T_ &gt;</a>	To handle square matrices in skyline storage format . . . . .	996
<a href="#">SkSMatrix&lt; T_ &gt;</a>	To handle symmetric matrices in skyline storage format . . . . .	1011
<a href="#">Sphere</a>	To store and treat a sphere . . . . .	1025
<a href="#">SpMatrix&lt; T_ &gt;</a>	To handle matrices in sparse storage format . . . . .	1027
<a href="#">SteklovPoincare2DBE</a>	Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary element . . . . .	1044

<a href="#">Tabulation</a>	To read and manipulate tabulated functions . . . . .	1046
<a href="#">Tetra4</a>	Defines a three-dimensional 4-node tetrahedral finite element using $P_1$ interpolation . . . . .	1047
<a href="#">Timer</a>	To handle elapsed time counting . . . . .	1049
<a href="#">TimeStepping</a>	To solve time stepping problems, i.e. systems of linear ordinary differential equations of the form $[A2]\{y''\} + [A1]\{y'\} + [A0]\{y\} = \{b\}$ . . . . .	1050
<a href="#">TINS2DT3S</a>	Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration . . . . .	1057
<a href="#">TINS3DT4S</a>	Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration . . . . .	1072
<a href="#">Triang3</a>	Defines a 3-Node ( $P_1$ ) triangle . . . . .	1088
<a href="#">Triang6S</a>	Defines a 6-Node straight triangular finite element using $P_2$ interpolation . . .	1091
<a href="#">triangle</a>	Defines a triangle. The reference element is the rectangle triangle with two unit edges . . . . .	??
<a href="#">Triangle</a>	To store and treat a triangle . . . . .	1096
<a href="#">TrMatrix&lt; T_ &gt;</a>	To handle tridiagonal matrices . . . . .	1098
<a href="#">UserData&lt; T_ &gt;</a>	Abstract class to define by user various problem data . . . . .	1108
<a href="#">Vect&lt; T_ &gt;</a>	To handle general purpose vectors . . . . .	1112
<a href="#">WaterPorous2D</a>	To solve water flow equations in porous media (1-D) . . . . .	1139

# Chapter 5

## Module Documentation

### 5.1 Conservation Law Equations

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.*

#### 5.1.1 Detailed Description

Conservation law equations.

## 5.2 Electromagnetics

Electromagnetic equations.

### 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 [EC2D2T3](#)  
*Eddy current problems in 2-D domains using transversal 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.*

### 5.2.1 Detailed Description

Electromagnetic equations.



## 5.3 Finite Element Mesh

Mesh management 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_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).get←  
ActiveElement());)`
- `#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).get←  
BoundaryNode());)`
- `#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).get←  
BoundarySide());)`

- #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 union 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.*

### 5.3.1 Detailed Description

Mesh management classes

### 5.3.2 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 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*

### 5.3.3 Function Documentation

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

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

Parameters

in	<i>f1</i>	First <a href="#">Figure</a> instance
in	<i>f2</i>	Second <a href="#">Figure</a> instance

Returns

Updated resulting [Figure](#) instance

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

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

Parameters

in	<i>f1</i>	First <a href="#">Figure</a> instance
in	<i>f2</i>	Second <a href="#">Figure</a> 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 <a href="#">Figure</a> instance to subtract from
in	<i>f2</i>	Second <a href="#">Figure</a> instance to subtract

## Returns

Updated resulting [Figure](#) instance

**ostream & operator<< ( ostream & s, const NodeList & nl )**

Output [NodeList](#) instance.

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**ostream & operator<< ( ostream & s, const ElementList & el )**

Output [ElementList](#) instance.

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**ostream & operator<< ( ostream & s, const SideList & sl )**

Output [SideList](#) instance.

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**ostream & operator<< ( ostream & s, const EdgeList & el )**

Output [EdgeList](#) instance.

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**size\_t Label ( const Node & nd )**

Return label of a given node.



## Parameters

in	<i>nd</i>	Reference to <a href="#">Node</a> instance
----	-----------	--

## Returns

Label of node

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**size\_t Label ( const Element & *el* )**

Return label of a given element.

## Parameters

in	<i>el</i>	Reference to <a href="#">Element</a> instance
----	-----------	---

## Returns

Label of element

## Author

Rachid Touzani

## Copyright

GNU Lesser Public License

**size\_t Label ( const Side & *sd* )**

Return label of a given side.

## Parameters

in	<i>sd</i>	Reference to <a href="#">Side</a> instance
----	-----------	--

## Returns

Label of side

## Author

Rachid Touzani

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**size\_t Label ( const Edge & *ed* )**

Return label of a given edge.

Parameters

in	<i>ed</i>	Reference to <a href="#">Edge</a> instance
----	-----------	--

Returns

Label of edge

Author

Rachid Touzani

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**size\_t NodeLabel ( const Element & *el*, size\_t *n* )**

Return global label of node local label in element.

Parameters

in	<i>el</i>	Reference to <a href="#">Element</a> instance
in	<i>n</i>	Local label of node in element

Returns

Global label of node

Author

Rachid Touzani

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**size\_t NodeLabel ( const Side & *sd*, size\_t *n* )**

Return global label of node local label in side.

## Parameters

in	<i>sd</i>	Reference to <a href="#">Side</a> instance
in	<i>n</i>	Local label of node in side

## Returns

Global label of node

## Author

Rachid Touzani

## Copyright

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

Return coordinates of a given node.

## Parameters

in	<i>nd</i>	Reference to <a href="#">Node</a> instance
----	-----------	--

## Returns

Coordinates of node

## Author

Rachid Touzani

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**int Code ( const Node & *nd*, size\_t *i* = 1 )**

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

## Parameters

in	<i>nd</i>	Reference to <a href="#">Node</a> instance
in	<i>i</i>	Label of dof [Default: 1]

## Returns

Code of dof of node

Author

Rachid Touzani

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**int Code ( const Element & *el* )**

Return code of a given element.

Parameters

in	<i>el</i>	Reference to <a href="#">Element</a> instance
----	-----------	---

Returns

Code of element

Author

Rachid Touzani

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**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 <a href="#">Side</a> instance
in	<i>i</i>	Label of dof [Default: 1]

Returns

Code of dof of side

Author

Rachid Touzani

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

Check equality between 2 elements.

## Parameters

in	<i>el1</i>	Reference to first <a href="#">Side</a> instance
in	<i>el2</i>	Reference to second <a href="#">Side</a> instance

## Returns

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

## Author

Rachid Touzani

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

Check equality between 2 sides.

## Parameters

in	<i>sd1</i>	Reference to first <a href="#">Side</a> instance
in	<i>sd2</i>	Reference to second <a href="#">Side</a> instance

## Returns

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

## Author

Rachid Touzani

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**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>	<a href="#">Mesh</a> 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

Author

Rachid Touzani

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**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>	<a href="#">Mesh</a> 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

Author

Rachid Touzani

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**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`

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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	<code>u1</code>	Input vector of nodal values defined on first mesh. This vector instance must contain <a href="#">Mesh</a> instance
out	<code>u2</code>	Output vector of nodal values defined on second mesh. This vector instance must contain <a href="#">Mesh</a> instance
in	<code>nx</code>	Number of cells in the x-direction in the fine structured grid
in	<code>ny</code>	Number of cells in the y-direction in the fine structured grid The default value of <code>ny</code> is 0, i.e. a 1-D grid
in	<code>nz</code>	Number of cells in the z-direction in the fine structured grid The default value of <code>nz</code> is 0, i.e. a 1-D or 2-D grid
in	<code>dof</code>	Label of degree of freedom of vector <code>u</code> . 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`

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```
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>	<a href="#">Point</a> instance containing minimal coordinates of the rectangle that defines the grid
in	<i>xmax</i>	<a href="#">Point</a> 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 <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*

#### Author

Rachid Touzani

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#### **real\_t getMaxSize ( const Mesh & *m* )**

Return maximal size of element edges for given mesh.

#### Parameters

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



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**real.t getMinSize ( const Mesh &  $m$  )**

Return minimal size of element edges for given mesh.

Parameters

in	$m$	Reference to mesh instance
----	-----	----------------------------

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Rachid Touzani

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**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	$m$	Reference to mesh instance
----	-----	----------------------------

Author

Rachid Touzani

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

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

Parameters

in	$m$	Reference to mesh instance
----	-----	----------------------------

## Note

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

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

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

## Parameters

in	$m$	Reference to mesh instance
----	-----	----------------------------

## Note

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

## Author

Rachid Touzani

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

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

## Parameters

in	$m$	Reference to mesh instance
----	-----	----------------------------

## Author

Rachid Touzani

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**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

## Author

Rachid Touzani

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**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 fparser 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 fparser parser
in	<i>code</i>	Code to assign
in	<i>dof</i>	Degree of freedom for which code is assigned [Default: 1]

## Author

Rachid Touzani

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**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]

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**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]

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**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

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Rachid Touzani

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**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 <a href="#">Node</a>
in	<i>el</i>	Pointer to <a href="#">Element</a>

Returns

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

Author

Rachid Touzani

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**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 <a href="#">Node</a>
in	<i>sd</i>	Pointer to <a href="#">Side</a>

Returns

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

Author

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**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 <a href="#">Side</a>
in	<i>el</i>	Pointer to <a href="#">Element</a>

## Returns

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

## Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const Node & nd )**

Output node data.

## Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const Side & sd )**

Output side data.

## Author

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## 5.4 Fluid Dynamics

Fluid Dynamics equations.

### 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 [TINS2DT3S](#)  
*Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*
- class [TINS3DT4S](#)  
*Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*

### 5.4.1 Detailed Description

Fluid Dynamics equations.

## 5.5 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.*

### 5.5.1 Detailed Description

Gathers equation related classes.

### 5.5.2 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 ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>be</i>	Local vector
in,out	<i>b</i>	Global vector

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**`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 ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>ae</i>	Local matrix
in,out	<i>b</i>	Global vector

Author

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**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	<i>e</i>	Reference to local entity ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>ae</i>	Local matrix
in,out	<i>A</i>	Pointer to global matrix

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**void element\_assembly ( const E\_ & *e*, const LocalMatrix< T\_, N\_, N\_ > & *ae*, SkMatrix< T\_ > & *A* )**

Assemble local matrix into global skyline matrix.

Parameters

in	<i>e</i>	Reference to local entity ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>ae</i>	Local matrix
in,out	<i>A</i>	Global matrix

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**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	<i>e</i>	Reference to local entity ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>ae</i>	Local matrix
in,out	<i>A</i>	Global matrix

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Rachid Touzani

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**void element\_assembly ( const E\_ & *e*, const LocalMatrix< T\_, N\_, N\_ > & *ae*, SpMatrix< T\_ > & *A* )**

Assemble local matrix into global sparse matrix.

Parameters

in	<i>e</i>	Reference to local entity ( <a href="#">Element</a> or <a href="#">Side</a> )
in	<i>ae</i>	Local matrix
in,out	<i>A</i>	Global matrix

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Rachid Touzani

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**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	<i>e</i>	Reference to local <a href="#">Element</a>
in	<i>ae</i>	Local matrix
in,out	<i>A</i>	Global matrix

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Rachid Touzani

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**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 <a href="#">Element</a>
in	$ae$	Local matrix
in,out	$A$	Global matrix

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Rachid Touzani

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**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 <a href="#">Element</a>
in	$ae$	Local matrix
in,out	$A$	Global matrix

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Rachid Touzani

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**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 <a href="#">Element</a>
in	$be$	Local vector
in,out	$b$	Global vector

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Rachid Touzani

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## 5.6 Global Variables

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](#)

### 5.6.1 Detailed Description

All global variables in the library.

### 5.6.2 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

## 5.7 Heat Transfer

Heat Transfer equations.

### 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.*

### 5.7.1 Detailed Description

Heat Transfer equations.



## 5.8 Input/Output

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.*
- `#define MAX\_FFT\_SIZE 15`  
*Maximal size for the FFT Table This table can be used by the FFT for any number of points from 2 up to [MAX\\_FFT\\_SIZE](#). For example, if [MAX\\_FFT\\_SIZE](#) = 14, then we can transform anywhere from 2 to  $2^{15}$  = 32,768 points, using the same sine and cosine table.*

#### 5.8.1 Detailed Description

Input/Output utility classes.

#### 5.8.2 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

## 5.9 Interface Problems

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.*

### 5.9.1 Detailed Description

Interface problems, including image processing.

## 5.10 Laplace equation

Laplace and Poisson equations.

### 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 [LaplaceDG2DP1](#)  
*To build and solve the linear system for the Poisson problem using the [DG](#)  $P_1$  2-D triangle element.*
- class [SteklovPoincare2DBE](#)  
*Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.*

### 5.10.1 Detailed Description

Laplace and Poisson equations.

## 5.11 OFELI

### Modules

- [Conservation Law Equations](#)  
*Conservation law equations.*
- [Electromagnetics](#)  
*Electromagnetic equations.*
- [Finite Element Mesh](#)  
*Mesh management classes*
- [Fluid Dynamics](#)  
*Fluid Dynamics equations.*
- [General Purpose Equations](#)  
*Gathers equation related classes.*
- [Global Variables](#)  
*All global variables in the library.*
- [Heat Transfer](#)  
*Heat Transfer equations.*
- [Input/Output](#)  
*Input/Output utility classes.*
- [Interface Problems](#)  
*Interface problems, including image processing.*
- [Laplace equation](#)  
*Laplace and Poisson equations.*
- [Physical properties of media](#)  
*Physical properties of materials and media.*
- [Porous Media problems](#)  
*Porous Media equation classes.*
- [Shape Function](#)  
*Shape function classes.*
- [Solid Mechanics](#)  
*Solid Mechanics finite element equations.*
- [Solver](#)  
*Solver functions and classes.*
- [Utilities](#)  
*Utility functions and classes.*
- [Vector and Matrix](#)  
*Vector and matrix classes.*

### Files

- file [AbsEqua.h](#)  
*Definition file for abstract class AbsEqua.*
- file [ICPG1D.h](#)  
*Definition file for class ICPG1D.*
- file [ICPG2DT.h](#)  
*Definition file for class ICPG2DT.*
- file [ICPG3DT.h](#)

- Definition file for class ICPG3DT.*

  - file [LCL1D.h](#)

*Definition file for class LCL1D.*

  - file [LCL2DT.h](#)

*Definition file for class LCL2DT.*

  - file [LCL3DT.h](#)

*Definition file for class LCL3DT.*

  - file [Muscl.h](#)

*Definition file for class Muscl.*

  - file [Muscl1D.h](#)

*Definition file for class Muscl1D.*

  - file [Muscl2DT.h](#)

*Definition file for class Muscl2DT.*

  - file [Muscl3DT.h](#)

*Definition file for class Muscl3DT.*

  - file [BiotSavart.h](#)

*Definition file for class BiotSavart.*

  - file [EC2D1T3.h](#)

*Definition file for class EC2D1T3.*

  - file [EC2D2T3.h](#)

*Definition file for class EC2D2T3.*

  - file [Equa\\_Electromagnetics.h](#)

*Definition file for class FE\_Electromagnetics.*

  - file [HelmholtzBT3.h](#)

*Definition file for class HelmholtzBT3.*

  - file [Equation.h](#)

*Definition file for class Equation.*

  - file [Equa\\_Fluid.h](#)

*Definition file for class Equa\_Fluid.*

  - file [NSP2DQ41.h](#)

*Definition file for class NSP2DQ41.*

  - file [TINS2DT3S.h](#)

*Definition file for class TINS2DT3S.*

  - file [TINS3DT4S.h](#)

*Definition file for class TINS3DT4S.*

  - file [Equa\\_Laplace.h](#)

*Definition file for class Equa\_Laplace.*

  - file [Laplace1DL2.h](#)

*Definition file for class Laplace1DL2.*

  - file [Laplace1DL3.h](#)

*Definition file for class Laplace1DL3.*

  - file [Laplace2DFVT.h](#)

*Definition file for class Laplace.*

  - file [Laplace2DMHRT0.h](#)

*Definition file for class Laplace2DMHRT0.*

  - file [Laplace2DT3.h](#)

- Definition file for class Laplace2DT3.*
- file [Laplace3DT4.h](#)
  - Definition file for class Laplace3DT4.*
- file [SteklovPoincare2DBE.h](#)
  - Definition file for class SteklovPoincare2DBE.*
- file [Equa\\_Porous.h](#)
  - Definition file for class Equa\_Porous.*
- file [WaterPorous1D.h](#)
  - Definition file for class WaterPorous1D.*
- file [WaterPorous2D.h](#)
  - Definition file for class WaterPorous2D.*
- file [Bar2DL2.h](#)
  - Definition file for class Bar2DL2.*
- file [Beam3DL2.h](#)
  - Definition file for class Beam3DL2.*
- file [Elas2DQ4.h](#)
  - Definition file for class Elas2DQ4.*
- file [Elas2DT3.h](#)
  - Definition file for class Elas2DT3.*
- file [Elas3DH8.h](#)
  - Definition file for class Elas3DH8.*
- file [Elas3DT4.h](#)
  - Definition file for class Elas3DT4.*
- file [Equa\\_Solid.h](#)
  - Definition file for class Equa\_Solid.*
- file [DC1DL2.h](#)
  - Definition file for class DC1DL2.*
- file [DC2DT3.h](#)
  - Definition file for class DC2DT3.*
- file [DC2DT6.h](#)
  - Definition file for class DC2DT6.*
- file [DC3DAT3.h](#)
  - Definition file for class DC3DAT3.*
- file [DC3DT4.h](#)
  - Definition file for class DC3DT4.*
- file [Equa\\_Therm.h](#)
  - Definition file for class Equa\_Therm.*
- file [PhaseChange.h](#)
  - Definition file for class PhaseChange and its parent abstract class.*
- file [Funct.h](#)
  - Definition file for class Funct.*
- file [IOField.h](#)
  - Definition file for class IOField.*
- file [IPF.h](#)
  - Definition file for class IPF.*
- file [output.h](#)

- *File that contains some output utility functions.*
- file [Prescription.h](#)  
*Definition file for class Prescription.*
- file [saveField.h](#)  
*Prototypes for functions to save mesh in various file formats.*
- file [saveField.h](#)  
*Prototypes for functions to save mesh in various file formats.*
- file [Tabulation.h](#)  
*Definition file for class Tabulation.*
- file [UserData.h](#)  
*Definition file for abstract class UserData.*
- file [BMatrix.h](#)  
*Definition file for class BMatrix.*
- file [DMatrix.h](#)  
*Definition file for class DMatrix.*
- file [DSMatrix.h](#)  
*Definition file for abstract class DSMatrix.*
- file [LocalMatrix.h](#)  
*Definition file for class LocalMatrix.*
- file [LocalVect.h](#)  
*Definition file for class LocalVect.*
- file [Matrix.h](#)  
*Definition file for abstract class Matrix.*
- file [PETScMatrix.h](#)  
*Definition file for class PETScMatrix.*
- file [Point.h](#)  
*Definition file and implementation for class Point.*
- file [Point2D.h](#)  
*Definition file for class Point2D.*
- file [SkMatrix.h](#)  
*Definition file for class SkMatrix.*
- file [SkSMatrix.h](#)  
*Definition file for class SkSMatrix.*
- file [SpMatrix.h](#)  
*Definition file for class SpMatrix.*
- file [TrMatrix.h](#)  
*Definition file for class TrMatrix.*
- file [Domain.h](#)  
*Definition file for class Domain.*
- file [Edge.h](#)  
*Definition file for class Edge.*
- file [Element.h](#)  
*Definition file for class Element.*
- file [Figure.h](#)  
*Definition file for figure classes.*
- file [getMesh.h](#)

- Definition file for mesh conversion functions.*
- file [Grid.h](#)
  - Definition file for class Grid.*
- file [Material.h](#)
  - Definition file for class Material.*
- file [Mesh.h](#)
  - Definition file for class Mesh.*
- file [MeshAdapt.h](#)
  - Definition file for class MeshAdapt.*
- file [MeshExtract.h](#)
  - Definition file for classes for extracting submeshes.*
- file [MeshUtil.h](#)
  - Definitions of utility functions for meshes.*
- file [Node.h](#)
  - Definition file for class Node.*
- file [saveMesh.h](#)
  - Prototypes for functions to save mesh in various file formats.*
- file [Side.h](#)
  - Definition file for class Side.*
- file [FEShape.h](#)
  - Definition file for class FEShape.*
- file [Hexa8.h](#)
  - Definition file for class Hexa8.*
- file [Line2.h](#)
  - Definition file for class Line2.*
- file [Line2H.h](#)
  - Definition file for class Line2H.*
- file [Line3.h](#)
  - Definition file for class Line3.*
- file [Penta6.h](#)
  - Definition file for class Penta6.*
- file [Quad4.h](#)
  - Definition file for class Quad4.*
- file [Tetra4.h](#)
  - Definition file for class Tetra4.*
- file [Triang3.h](#)
  - Definition file for class Triang3.*
- file [Triang6S.h](#)
  - Definition file for class Triang6S.*
- file [BiCG.h](#)
  - Solves an unsymmetric linear system of equations using the BiConjugate Gradient method.*
- file [BSpline.h](#)
  - Function to perform a B-spline interpolation.*
- file [CG.h](#)
  - Functions to solve a symmetric positive definite linear system of equations using the Conjugate Gradient method.*
- file [CGS.h](#)



- Solves an unsymmetric linear system of equations using the Conjugate Gradient Squared method.*

  - file [EigenProblemSolver.h](#)  
*Definition file for class EigenProblemSolver.*
- file [GMRes.h](#)  
*Function to solve a linear system of equations using the Generalized Minimum Residual method.*
- file [GS.h](#)  
*Function to solve a linear system of equations using the Gauss-Seidel method.*
- file [Jacobi.h](#)  
*Function to solve a linear system of equations using the Jacobi method.*
- file [MyNLAS.h](#)  
*Definition file for abstract class MyNLAS.*
- file [MyOpt.h](#)  
*Definition file for abstract class MyOpt.*
- file [ODESolver.h](#)  
*Definition file for class ODESolver.*
- file [Prec.h](#)  
*Definition file for preconditioning classes.*
- file [Richardson.h](#)  
*Function to solve a linear system of equations using the Richardson method.*
- file [SSOR.h](#)  
*Function to solve a linear system of equations using the Symmetric Successive Over Relaxation method.*
- file [TimeStepping.h](#)  
*Definition file for class TimeStepping.*
- file [constants.h](#)  
*File that contains some widely used constants.*
- file [Gauss.h](#)  
*Definition file for struct Gauss.*
- file [qksort.h](#)  
*File that contains template quick sorting function.*
- file [Timer.h](#)  
*Definition file for class Timer.*
- file [util.h](#)  
*File that contains various utility functions.*

## Classes

- 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 [AbsEqua< T\\_ >](#)  
*Mother abstract class to describe equation.*
- class [LocalVect< T\\_, N\\_ >](#)  
*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< T\\_ >](#)
- 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 [EC2D2T3](#)
- Eddy current problems in 2-D domains using transversal 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.*

  - class [Equation< T\\_, NEN\\_, NEE\\_, NSN\\_, NSE\\_ >](#)
- Abstract class for all equation 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 [TINS2DT3S](#)
- Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*

  - class [TINS3DT4S](#)
- Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*

  - 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< 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.*
- class [Equa.Porous< T\\_, NEN\\_, NEE\\_, NSN\\_, NSE\\_ >](#)  
*Abstract class for Porous Media Finite Element classes.*
- class [WaterPorous2D](#)  
*To solve water flow equations in porous media (1-D)*
- 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.*
- 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.*
- 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< T\\_ >](#)

*Abstract class to define by user various problem data.*
- 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 [Matrix< T\\_ >](#)

*Virtual class to handle matrices for all storage formats.*
- class [PETScVect< T\\_ >](#)

*To handle general purpose vectors using Petsc.*
- class [PETScMatrix< T\\_ >](#)

*To handle matrices in sparse storage format using the Petsc library.*
- class [PETScWrapper< T\\_ >](#)

*This class is a wrapper to be used when the library Petsc is installed and used with [OFELI](#).*
- class [Point< T\\_ >](#)

*Defines a point with arbitrary type coordinates.*
- class [Point2D< T\\_ >](#)

*Defines a 2-D point with arbitrary type coordinates.*
- class [LinearSolver< T\\_ >](#)

*Class to solve systems of linear equations by iterative methods.*
- class [TrMatrix< T\\_ >](#)

*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 [OFELIException](#)
  - To handle exceptions in [OFELI](#).*
- 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 [Prec< T\\_ >](#)  
*To set a preconditioner.*
- 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 [MyNLAS](#)  
*Abstract class to define by user specified function.*
- class [MyOpt](#)  
*Abstract class to define by user specified optimization function.*
- 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

## Functions

- `T_ * A ()`  
*Return element matrix.*
- `T_ * b ()`  
*Return element right-hand side.*
- `T_ * Prev ()`  
*Return element previous vector.*
- `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 (const string &file, AccessType access, const string &name)`  
*Constructor using file name and field name.*
- `~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, const string &name)`  
*Get Vect v instance from file if the field has the given name.*
- `int get (DMatrix< real_t > &A, const string &name)`  
*Get DMatrix A instance from file if the field has the given name.*
- `int get (DSMatrix< real_t > &A, const string &name)`  
*Get DSMatrix A instance from file if the field has the given name.*
- `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.*
- **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.*
- **Point< double > CrossProduct** (const **Point< double >** &lp, const **Point< double >** &rp)
  - Return Cross product of two vectors lp and rp*
- **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)
  - Set max. coordinates of the domain.*
- 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)*
- `ostream & operator<< (ostream &s, const Grid &g)`  
*Output grid data.*
- `OFELIException (const std::string &s)`  
*This form will be used most often in a throw.*
- `OFELIException ()`  
*Throw with no error message.*
- `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](#).*
- `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.*
- `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.*
- `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.*

- `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_ operator,` (`const LocalVect< T_, N_ > &v`) `const`  
*Return Dot (scalar) product of two vectors.*
- `Iter ()`  
*Default Constructor.*
- `Iter` (`int max_it`, `real_t toler`, `int verbose=0`)  
*Constructor with iteration parameters.*
- `bool check` (`Vect< T_ > &u`, `const Vect< T_ > &v`, `int opt=2`)  
*Check convergence.*
- `bool check` (`T_ &u`, `const T_ &v`)  
*Check convergence for a scalar case (one equation)*

### 5.11.1 Detailed Description

### 5.11.2 Enumeration Type Documentation

#### **enum** PDE\_Terms

Enumerate variable that selects various terms in partial differential equations

Enumerator

**CONSISTENT\_MASS** Consistent mass term  
**LUMPED\_MASS** Lumped mass term  
**MASS** Consistent 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  
**MOBILITY** Mobility 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 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

*DENSE* Dense storage  
*SKYLINE* Skyline storage  
*SPARSE* Sparse storage  
*DIAGONAL* Diagonal storage  
*TRIDIAGONAL* Tridiagonal storage  
*BAND* Band 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

### 5.11.3 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.

**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]

**IOField ( const string & *file*, AccessType *access*, const string & *name* )**

Constructor using file name and field name.

Parameters

in	<i>file</i>	File that contains field stored or to store
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>name</i>	Seek a specific field with given <i>name</i>

**void setMeshFile ( const string & *file* )**

Set mesh file.

Parameters

in	<i>file</i>	<a href="#">Mesh</a> file
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**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

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>• <code>IOField::IN</code> to read the file</li> <li>• <code>IOField::OUT</code> to write on it</li> </ul>

**void put ( const Vect< real.t > & v )**

Store [Vect](#) instance *v* in file.

## Parameters

in	<i>v</i>	<a href="#">Vect</a> instance to store
----	----------	--

**void put ( const PETScVect< real.t > & v )**

Store [PETScVect](#) instance *v* in file.

## Parameters

in	<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, const string & name )**

Get [Vect](#) *v* instance from file if the field has the given name.

First time step is read from the XML file.

## Parameters

in,out	<i>v</i>	<a href="#">Vect</a> instance
in	<i>name</i>	Name to seek in the XML file

**int get ( DMatrix< real.t > & A, const string & name )**

Get [DMatrix](#) *A* instance from file if the field has the given name.

First time step is read from the XML file.

## Parameters

in,out	<i>A</i>	<a href="#">DMatrix</a> instance
--------	----------	----------------------------------

Parameters

in	<i>name</i>	Name to seek in the XML file
----	-------------	------------------------------

**int get ( DSMatrix< real.t > & A, const string & name )**

Get [DSMatrix](#) A instance from file if the field has the given name.  
First time step is read from the XML file.

Parameters

in,out	<i>A</i>	<a href="#">DSMatrix</a> instance
in	<i>name</i>	Name to seek in 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

in,out	<i>v</i>	Vector instance
in	<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

in	<i>output_file</i>	Output file name where to store using <b>GMSH</b> format
in	<i>mesh_file</i>	File containing mesh data

**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
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Parameters

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>funct</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

**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

in	<i>xm</i>	Minimal value for x
in	<i>xM</i>	Maximal value for x
in	<i>npx</i>	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

in	<i>xm</i>	Minimal value for x
in	<i>xM</i>	Maximal value for x
in	<i>ym</i>	Minimal value for y
in	<i>yM</i>	Maximal value for y
in	<i>npx</i>	Number of grid intervals in the x-direction
in	<i>npy</i>	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

in	<i>m</i>	Minimal coordinate value
in	<i>M</i>	Maximal coordinate value
in	<i>npx</i>	Number of grid intervals in the x-direction
in	<i>npy</i>	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

in	<i>xm</i>	Minimal value for x
in	<i>xM</i>	Maximal value for x

Parameters

in	$ym$	Minimal value for y
in	$yM$	Maximal value for y
in	$zm$	Minimal value for z
in	$zM$	Maximal value for z
in	$npx$	Number of grid intervals in the x-direction
in	$npz$	Number of grid intervals in the y-direction
in	$npz$	Number of grid intervals in the z-direction

**Grid ( Point< real\_t >  $m$ , Point< real\_t >  $M$ , size\_t  $npx$ , size\_t  $npz$ , size\_t  $npz$  )**

Construct a 3-D structured grid given its extremal coordinates and number of intervals.

Parameters

in	$m$	Minimal coordinate value
in	$M$	Maximal coordinate value
in	$npx$	Number of grid intervals in the x-direction
in	$npz$	Number of grid intervals in the y-direction
in	$npz$	Number of grid intervals in the z-direction

**void setXMin ( const Point< real\_t > & $x$  )**

Set min. coordinates of the domain.

Parameters

in	$x$	Minimal values of coordinates
----	-----	-------------------------------

**void setXMax ( const Point< real\_t > & $x$  )**

Set max. coordinates of the domain.

Parameters

in	$x$	Maximal values of coordinates
----	-----	-------------------------------

**void setDomain ( real\_t  $xmin$ , real\_t  $xmax$  )**

Set Dimensions of the domain: 1-D case.

Parameters

in	$xmin$	Minimal value of x-coordinate
in	$xmax$	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

in	<i>xmin</i>	Minimal value of x-coordinate
in	<i>xmax</i>	Maximal value of x-coordinate
in	<i>ymin</i>	Minimal value of y-coordinate
in	<i>ymax</i>	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

in	<i>xmin</i>	Minimal value of x-coordinate
in	<i>xmax</i>	Maximal value of x-coordinate
in	<i>ymin</i>	Minimal value of y-coordinate
in	<i>ymax</i>	Maximal value of y-coordinate
in	<i>zmin</i>	Minimal value of z-coordinate
in	<i>zmax</i>	Maximal value of z-coordinate

**void setDomain ( Point< real\_t > xmin, Point< real\_t > xmax )**

Set Dimensions of the domain: 3-D case.

Parameters

in	<i>xmin</i>	Minimal coordinate value
in	<i>xmax</i>	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

in	<i>nx</i>	Number of grid intervals in the x-direction
in	<i>ny</i>	Number of grid intervals in the y-direction (Default=0: 1-D grid)
in	<i>nz</i>	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	<i>exp</i>	Regular expression that determines the set of grid points on which the code is applied.
in	<i>code</i>	Code to assign.

**void setCode ( int side, int code )**

Set a code for grid points on sides.

## Parameters

in	<i>side</i>	<a href="#">Side</a> for which code is assigned. Possible values are: <code>MIN_X</code> , <code>MAX_X</code> , <code>MIN_Y</code> , <code>MAX_Y</code> , <code>MIN_Z</code> , <code>MAX_Z</code>
in	<i>code</i>	Code to assign.

**int getCode ( int side ) const**

Return code for a side number.

## Parameters

in	<i>side</i>	<a href="#">Side</a> for which code is returned. Possible values are: <code>MIN_X</code> , <code>MAX_X</code> , <code>MIN_Y</code> , <code>MAX_Y</code> , <code>MIN_Z</code> , <code>MAX_Z</code>
----	-------------	---

**int getCode ( size\_t i, size\_t j ) const**

Return code for a grid point.

## Parameters

in	<i>i</i>	<i>i</i> -th index for node for which code is to be returned.
----	----------	---



Parameters

in	<i>j</i>	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</i>	i-th index for node for which code is to be returned.
in	<i>j</i>	j-th index for node for which code is to be returned.
in	<i>k</i>	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

in	<i>i</i>	grid cell to remove
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**void Deactivate ( size\_t *i*, size\_t *j* )**

Change state of a cell from active to inactive (2-D grid)

Parameters

in	<i>i</i>	i-th index for grid cell to remove. If this value is 0, all cells (*, j) are deactivated
in	<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

in	<i>i</i>	i-th index for grid cell to remove. If this value is 0, all cells (*, j, k) are deactivated
in	<i>j</i>	j-th index for grid cell to remove If this value is 0, all cells (i, *, k) are deactivated
in	<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

in	<i>i</i>	Index of cell
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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

in	<i>i</i>	i-th index of cell
in	<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</i>	i-th index of cell
in	<i>j</i>	j-th index of cell
in	<i>k</i>	k-th index of cell

Returns

1 if cell is active, 0 if not

**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>
----	-----------	------------------------------------

Parameters

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> .

**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\_ > & *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\_ > & *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\_, NR\_, NC\_ > & operator= ( const LocalMatrix< T\_, NR\_, NC\_ > & m )**

Operator =

Copy instance m into current instance.

**LocalMatrix< T\_, NR\_, NC\_ > & operator= ( const T\_ & x )**

Operator =

Assign matrix to identity times x

**LocalMatrix< T\_, NR\_, NC\_ > & operator+= ( const LocalMatrix< T\_, NR\_, NC\_ > & m )**

Operator +=

Add m to current matrix.

**LocalMatrix< T\_, NR\_, NC\_ > & operator-= ( const LocalMatrix< T\_, NR\_, NC\_ > & m )**

Operator -=

Subtract m from current matrix.

**LocalVect< T\_, NR\_ > operator\* ( LocalVect< T\_, NC\_ > & x )**

Operator \*

Return a [Vect](#) instance as product of current matrix by vector x.

**LocalMatrix< T\_, NR\_, NC\_ > & operator+= ( const T\_ & x )**

Operator +=

Add constant x to current matrix entries.

**LocalMatrix< T\_, NR\_, NC\_ > & operator-= ( const T\_ & x )**

Operator -=

Subtract x from current matrix entries.

**LocalMatrix< T\_, NR\_, NC\_ > & operator\*= ( const T\_ & x )**

Operator \*=

Multiply matrix entries by constant x.

**LocalMatrix< T\_, NR\_, NC\_ > & operator/= ( const T\_ & x )**

Operator /=

Divide by x current matrix entries.

**void MultAdd ( const LocalVect< T\_, NC\_ > & *x*, LocalVect< T\_, NR\_ > & *y* )**

Multiply matrix by vector and add result to vector.

Parameters

in	$x$	Vector to multiply matrix by.
out	$y$	Resulting vector ( $y += a * x$ )

**void MultAddScal ( const T\_ &  $a$ , const LocalVect< T\_, NC\_ > &  $x$ , LocalVect< T\_, NR\_ > &  $y$  )**

Multiply matrix by scaled vector and add result to vector.

Parameters

in	$a$	Constant to premultiply by vector $x$ .
in	$x$	(Scaled) vector to multiply matrix by.
out	$y$	Resulting vector ( $y += a * x$ )

**void Mult ( const LocalVect< T\_, NC\_ > &  $x$ , LocalVect< T\_, NR\_ > &  $y$  )**

Multiply matrix by vector.

Parameters

in	$x$	Vector to multiply matrix by.
out	$y$	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  $x^T A y$

## Parameters

in	$x$	Left vector
in	$y$	Right vector

## Returns

Resulting product

**LocalVect ( const Element \* el, const Vect< T\_ > & 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 <a href="#">Element</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>

**LocalVect ( const Side \* *sd*, const Vect< T\_ > & *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>

**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
----	-----------	---



Parameters

in	$v$	Global vector to localize
in	$k$	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	$sd$	Pointer to Side to localize
in	$v$	Global vector to localize
in	$k$	Degree of freedom to localize [Default: All degrees of freedom are stored]

**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	<i>v</i>	LocalVect instance by which the current instance is multiplied
----	----------	--

**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.

**bool check ( Vect< T\_ > & u, const Vect< T\_ > & v, int opt = 2 )**

Check convergence.

Parameters

in,out	<i>u</i>	Solution vector at previous iteration
in	<i>v</i>	Solution vector at current iteration
in	<i>opt</i>	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.

**bool check ( T\_ &  $u$ , const T\_ &  $v$  )**

Check convergence for a scalar case (one equation)

Parameters

in,out	$u$	Solution at previous iteration
in	$v$	Solution at current iteration

Returns

true if convergence criterion is satisfied, false if not

After checking, this function copied  $v$  into  $u$ .

## 5.12 Physical properties of media

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

Physical properties of materials and media.

## 5.13 Porous Media problems

Porous Media equation classes.

### Classes

- class `Equa_Porous< T_, NEN_, NEE_, NSN_, NSE_ >`  
*Abstract class for Porous Media Finite Element classes.*

### 5.13.1 Detailed Description

Porous Media equation classes.

## 5.14 Shape Function

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.*

### 5.14.1 Detailed Description

Shape function classes.

## 5.15 Solid Mechanics

Solid Mechanics finite element equations.

### 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.*

### 5.15.1 Detailed Description

Solid Mechanics finite element equations.

## 5.16 Solver

Solver functions and classes.

### 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  $\lambda$  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.*
- class [Iter< T\\_ >](#)  
*Class to drive an iterative process.*
- class [LinearSolver< T\\_ >](#)  
*Class to solve systems of linear equations by iterative methods.*
- class [MyNLAS](#)  
*Abstract class to define by user specified function.*
- class [MyOpt](#)  
*Abstract class to define by user specified optimization function.*
- class [NLASSolver](#)  
*To solve a system of nonlinear algebraic equations of the form  $f(u) = 0$ .*
- class [ODESolver](#)  
*To solve a system of ordinary differential equations.*
- class [OptSolver](#)  
*To solve an optimization problem with bound constraints.*
- 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.*
- ostream & **operator<<** (ostream &s, const NLASSolver &nl)  
*Output nonlinear system information.*
- ostream & **operator<<** (ostream &s, const ODESolver &de)  
*Output differential system information.*
- ostream & **operator<<** (ostream &s, const OptSolver &os)  
*Output differential system information.*

- `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

Solver functions and classes.

### 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`

Warning

The variable `theIteration` must be zeroed before using this macro

### 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 <a href="#">SpMatrix</a> ).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDENT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class <a href="#">Vect</a> )
in,out	<i>x</i>	<a href="#">Vect</a> 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"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

Returns

Number of performed iterations,

Template Parameters

<i>&lt;T↔ -&gt;</i>	Data type (double, float, complex<double>, ...)
-------------------------	---

Author

Rachid Touzani

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```
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 <a href="#">SpMatrix</a> ).
in	$P$	Preconditioner (Instance of class <a href="#">Prec</a> ).
in	$b$	Right-hand side vector (class <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> 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"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

Returns

Number of performed iterations,

Template Parameters

$\langle T_{\leftarrow} \rightarrow$	Data type (double, float, complex<double>, ...)
--------------------------------------	---

Author

Rachid Touzani

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```
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 <a href="#">SpMatrix</a> ).
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 <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> 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"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

## Returns

Number of performed iterations,

## Template Parameters

$\langle T_{\leftrightarrow} \rightarrow$	Data type (double, float, complex<double>, ...)
---	---

## Author

Rachid Touzani

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```
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

in	$A$	Problem matrix (Instance of class <a href="#">SpMatrix</a> ).
in	$P$	Preconditioner (Instance of class <a href="#">Prec</a> ).
in	$b$	Right-hand side vector (class <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).

## Parameters

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"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

## Returns

Number of performed iterations,

## Template Parameters

<i>&lt;T↔ -&gt;</i>	Data type (double, float, complex<double>, ...)
-------------------------	---

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```
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

in	<i>A</i>	Problem matrix (Instance of abstract class <a href="#">SpMatrix</a> ).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDENT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class <a href="#">Vect</a> )
in,out	<i>x</i>	<a href="#">Vect</a> 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).

## Parameters

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

## Returns

Number of performed iterations,

## Template Parameters

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

## Author

Rachid Touzani

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**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 <a href="#">SpMatrix</a> ).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDENT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class <a href="#">Vect</a> )
in,out	<i>x</i>	<a href="#">Vect</a> instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	<i>max<math>\leftrightarrow</math>_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"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

## Returns

Number of performed iterations

## Template Parameters

$\langle T_{\leftrightarrow} \rightarrow$	Data type (real_t, float, complex<real_t>, ...)
---	---

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**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 <a href="#">SpMatrix</a> ).
in	$P$	Preconditioner (Instance of class <a href="#">Prec</a> ).
in	$b$	Right-hand side vector (class <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> 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	$max_{\leftrightarrow} \_it$	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

$\langle T_{\leftrightarrow} \rightarrow$	Data type (double, float, complex<double>, ...)
---	---



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**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	<i>A</i>	Problem matrix (Instance of class <a href="#">SpMatrix</a> ).
in	<i>prec</i>	Enum variable selecting a preconditioner, among the values IDENT_PREC, DIAG_PREC, ILU_PREC or SSOR_PREC
in	<i>b</i>	Right-hand side vector (class <a href="#">Vect</a> )
in,out	<i>x</i>	<a href="#">Vect</a> instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	<i>m</i>	Number of subspaces to generate for iterations.
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

Number of performed iterations,

Template Parameters

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

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**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.

## Parameters

in	$A$	Problem matrix (Instance of class <a href="#">SpMatrix</a> ).
in	$b$	Right-hand side vector (class <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	$\omega$	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"> <li>• 0: No output</li> <li>• 1: Output iteration information</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

## Returns

Number of performed iterations

## Template Parameters

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

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**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.

## Parameters

in	$A$	Problem matrix (Instance of class <a href="#">SpMatrix</a> ).
in	$b$	Right-hand side vector (class <a href="#">Vect</a> )
in,out	$x$	<a href="#">Vect</a> instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	$\omega$	Relaxation parameter.

## Parameters

in	$max_{\leftarrow}it$	Maximum number of iterations.
in,out	<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

Number of performed iterations,

## Template Parameters

$\langle T\_ \rangle$	Data type (real_t, float, complex<real_t>, ...)
$\langle M_{\leftarrow} \_ \rangle$	Matrix storage class

## Author

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**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 <b>M_</b> ).
in	<i>b</i>	Right-hand side vector (class <a href="#">Vect</a> )
	<i>x</i>	<a href="#">Vect</a> 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	$max_{\leftarrow}it$	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

$\langle T\_ \rangle$	Data type (real.t, float, complex<real.t>, ...)
$\langle M\_ \leftarrow \_ \rangle$	Matrix storage class

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**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 <a href="#">SkMatrix</a> class for the first diagonal block. The matrix must be invertible and factorizable (Do not use <a href="#">SpMatrix</a> class) where A, U, L, D are instances of matrix classes,
in	$U$	Instance of class <a href="#">SpMatrix</a> for the upper triangle block. The matrix can be rectangular
in	$L$	Instance of class <a href="#">SpMatrix</a> for the lower triangle block. The matrix can be rectangular
in	$D$	Instance of class <a href="#">SpMatrix</a> for the second diagonal block. The matrix must be factorizable (Do not use <a href="#">SpMatrix</a> class)
in,out	$b$	Vector (Instance of class <a href="#">Vect</a> ) 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	$c$	<a href="#">Vect</a> 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

$\langle T \leftarrow$ $\rightarrow$	data type (real.t, float, ...)
---	--------------------------------

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**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 <a href="#">SkMatrix</a> class for the first diagonal block. The matrix must be invertible and factorizable (Do not use <a href="#">SpMatrix</a> class) where A, U, L, D are instances of matrix classes,
in	$U$	Instance of class <a href="#">PETScMatrix</a> for the upper triangle block. The matrix can be rectangular
in	$L$	Instance of class <a href="#">PETScMatrix</a> for the lower triangle block. The matrix can be rectangular
in	$D$	Instance of class <a href="#">PETScMatrix</a> for the second diagonal block. The matrix must be factorizable (Do not use <a href="#">SpMatrix</a> class)
in,out	$b$	Vector (Instance of class <a href="#">PETScVect</a> ) 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	$c$	<a href="#">PETScVect</a> 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

$\langle T \leftarrow$ $\rightarrow$	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	<i>A</i>	Problem matrix (Instance of abstract class <b>M_</b> ).
in	<i>b</i>	Right-hand side vector (class <b>Vect</b> )
in,out	<i>x</i>	<b>Vect</b> 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 (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

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

Output differential system information.

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## 5.17 Utilities

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 [Funct](#)  
*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 [OFELIException](#)  
*To handle exceptions in [OFELI](#).*
- 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)`
- `#define CATCH\_EXCEPTION`

## 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 `saveGnuplot` (Mesh &mesh, string input\_file, string output\_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 `saveTecplot` (Mesh &mesh, string input\_file, string output\_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 `saveVTK` (Mesh &mesh, string input\_file, string output\_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.*
- void `saveGmsh` (Mesh &mesh, string input\_file, string output\_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 &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  $y$*
  - `real_t exprep (real_t x)`  
*Compute the exponential function with avoiding over and underflows.*
  - `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`  $\text{toler}=\text{OFELLEPSMCH}$ )

*Function to return true if numbers  $x$  and  $y$  are close up to a given tolerance  $\text{toler}$*
- 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.*

### 5.17.1 Detailed Description

Utility functions and classes.

### 5.17.2 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  $d[0]=1$ ,  $d[1]=2$

**#define CATCH\_EXCEPTION**

**Value:**

```
catch(OFELIException &e) {
    std::cout << "OFELI exception: " << e.what() << endl;
    return 1;
}
catch(runtime_error &e) {
    std::cout << "Runtime exception: " << e.what() << endl;
    return 1;
}
catch( ... ) {
    std::cout << "Unexpected Exception: " << endl;
    return 1;
}
```

This macro can be inserted after a try loop to catch a thrown exception.

### 5.17.3 Function Documentation

**ostream & operator<< ( ostream & s, const complex\_t & x )**

Output a complex number.

Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const std::string & c )**

Output a string.

Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const vector< T\_ > & v )**

Output a vector instance.

Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const std::pair< T\_, T\_ > & a )**

Output a pair instance.

Author

Rachid Touzani

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**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>	<a href="#">Vect</a> 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

Author

Rachid Touzani



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**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>	<a href="#">PETScVect</a> 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

## Author

Rachid Touzani

## Copyright

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**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>	<a href="#">PETScVect</a> instance to save
in	<i>mesh</i>	<a href="#">Mesh</a> 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

## Author

Rachid Touzani

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**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>	<a href="#">Vect</a> instance to save
in	<i>g</i>	<a href="#">Grid</a> 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, VTK

## Author

Rachid Touzani

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**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 ( <a href="#">OFELI</a> XML file containing a field).
in	<i>output_file</i>	Output file (gnuplot format file)
in	<i>mesh_file</i>	File containing mesh data

## Author

Rachid Touzani

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**void saveGnuplot ( Mesh & *mesh*, string *input\_file*, string *output\_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>mesh</i>	Reference to <a href="#">Mesh</a> instance
in	<i>input_file</i>	Input file ( <a href="#">OFELI</a> XML file containing a field).
in	<i>output_file</i>	Output file (gnuplot format file)

Author

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

Author

Rachid Touzani

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**void saveTecplot ( Mesh & *mesh*, string *input\_file*, string *output\_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>mesh</i>	Reference to <b>Mesh</b> instance
in	<i>input_file</i>	Input file ( <b>OFELI</b> XML file containing a field).
in	<i>output_file</i>	Output file (gnuplot format file)

Author

Rachid Touzani

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**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

Author

Rachid Touzani

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**saveVTK ( Mesh & mesh, string input\_file, string output\_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>mesh</i>	Reference to Mesh instance
in	<i>input_file</i>	Input file (OFELI XML file containing a field).
in	<i>output_file</i>	Output file (VTK format file)

Author

Rachid Touzani

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**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

Author

Rachid Touzani

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**void saveGmsh ( Mesh & *mesh*, string *input\_file*, string *output\_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>mesh</i>	Reference to <b>Mesh</b> instance
in	<i>input_file</i>	Input file ( <b>OFELI</b> XML file containing a field).
in	<i>output_file</i>	Output file (Gmsh format file)

Author

Rachid Touzani

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**bool operator== ( const Point< T\_ > & *a*, const Point< T\_ > & *b* )**

Operator ==

Return true if a=b, false if not.

Author

Rachid Touzani

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**Point< T\_ > operator+ ( const Point< T\_ > & *a*, const Point< T\_ > & *b* )**

Operator +

Return sum of two points a and b

Author

Rachid Touzani

Copyright

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**Point< T\_ > operator+ ( const Point< T\_ > & a, const T\_ & x )**

Operator +  
Translate a by x

Author  
Rachid Touzani

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**Point< T\_ > operator- ( const Point< T\_ > & a )**

Unary Operator -  
Return minus a

Author  
Rachid Touzani

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**Point< T\_ > operator- ( const Point< T\_ > & a, const Point< T\_ > & b )**

Operator -  
Return point a minus point b

Author  
Rachid Touzani

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**Point< T\_ > operator- ( const Point< T\_ > & a, const T\_ & x )**

Operator -  
Translate a by -x

Author  
Rachid Touzani

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**Point< T\_ > operator\* ( const T\_ & a, const Point< T\_ > & b )**

Operator \*

Return point b premultiplied by constant a

Author

Rachid Touzani

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**Point< T\_ > operator\* ( const int & a, const Point< T\_ > & b )**

Operator \*.

Return point b divided by integer constant a

Author

Rachid Touzani

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**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

Author

Rachid Touzani

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**T\_ operator\* ( const Point< T\_ > & b, const Point< T\_ > & a )**

Operator \*

Return inner (scalar) product of points a and b

Author

Rachid Touzani

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**Point< T\_ > operator/ ( const Point< T\_ > & b, const T\_ & a )**

Operator /

Return point b divided by constant a

Author

Rachid Touzani

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**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

Author

Rachid Touzani

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**double SqrDistance ( const Point< double > & a, const Point< double > & b )**

Return squared euclidean distance between points a and b

Author

Rachid Touzani

Copyright

GNU Lesser Public License

**double Distance ( const Point< double > & a, const Point< double > & b )**

Return euclidean distance between points a and b

Author

Rachid Touzani

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**ostream & operator<< ( std::ostream & s, const Point< T\_ > & a )**

Output point coordinates.

Author

Rachid Touzani

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**bool operator== ( const Point2D< T\_ > & a, const Point2D< T\_ > & b )**

Operator ==.

Return true if a=b, false if not.

Author

Rachid Touzani

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**Point2D< T\_ > operator+ ( const Point2D< T\_ > & a, const Point2D< T\_ > & b )**

Operator +.

Return sum of two points a and b

Author

Rachid Touzani

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**Point2D< T\_ > operator+ ( const Point2D< T\_ > & a, const T\_ & x )**

Operator +.

Translate a by x

Author

Rachid Touzani

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**Point2D< T\_ > operator- ( const Point2D< T\_ > & a )**

Unary Operator -  
Return minus a

Author  
Rachid Touzani

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**Point2D< T\_ > operator- ( const Point2D< T\_ > & a, const Point2D< T\_ > & b )**

Operator -  
Return point a minus point b

Author  
Rachid Touzani

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**Point2D< T\_ > operator- ( const Point2D< T\_ > & a, const T\_ & x )**

Operator -  
Translate a by -x

Author  
Rachid Touzani

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**Point2D< T\_ > operator\* ( const T\_ & a, const Point2D< T\_ > & b )**

Operator \*.  
Return point b premultiplied by constant a

Author  
Rachid Touzani

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**Point2D< T\_ > operator\* ( const int & *a*, const Point2D< T\_ > & *b* )**

Operator \*.

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

Author

Rachid Touzani

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**Point2D< T\_ > operator\* ( const Point2D< T\_ > & *b*, const T\_ & *a* )**

Operator /

Return point *b* postmultiplied by constant *a*

Author

Rachid Touzani

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**Point2D< T\_ > operator\* ( const Point2D< T\_ > & *b*, const int & *a* )**

Operator \*

Return point *b* postmultiplied by constant *a*

Author

Rachid Touzani

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**T\_ operator\* ( const Point2D< T\_ > & *b*, const Point2D< T\_ > & *a* )**

Operator \*.

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

Author

Rachid Touzani

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**Point2D< T\_ > operator/ ( const Point2D< T\_ > & b, const T\_ & a )**

Operator /

Return point b divided by constant a

Author

Rachid Touzani

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**real.t SqrDistance ( const Point2D< real.t > & a, const Point2D< real.t > & b )**

Return squared euclidean distance between points a and b

Author

Rachid Touzani

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**real.t Distance ( const Point2D< real.t > & a, const Point2D< real.t > & b )**

Return euclidean distance between points a and b

Author

Rachid Touzani

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**ostream & operator<< ( std::ostream & s, const Point2D< T\_ > & a )**

Output point coordinates.

Author

Rachid Touzani

Copyright

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**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"> <li>• GMSH: Mesh generator <b>Gmsh</b>, see site: <a href="http://www.geuz.org/gmsh/">http://www.geuz.org/gmsh/</a></li> <li>• MATLAB: Matlab file, see site: <a href="http://www.mathworks.com/products/matlab/">http://www.mathworks.com/products/matlab/</a></li> <li>• EASYMESH: <b>Easymesh</b> is a 2-D mesh generator, see site: <a href="http://web.mit.edu/easymesh_v1.4/www/easymesh.html">http://web.mit.edu/easymesh_v1.4/www/easymesh.html</a></li> <li>• GAMBIT: <b>Gambit</b> is a mesh generator associated to <b>Fluent</b> <a href="http://www.stanford.edu/class/me469b/gambit_download.html">http://www.stanford.edu/class/me469b/gambit_download.html</a></li> <li>• BAMG: Mesh generator Bamg, see site: <a href="http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html">http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html</a></li> <li>• NETGEN: <b>Netgen</b> is a 3-D mesh generator, see site: <a href="http://www.hpfem.jku.at/netgen/">http://www.hpfem.jku.at/netgen/</a></li> <li>• TETGEN: <b>Tetgen</b> is a 3-D mesh generator, see site: <a href="http://tetgen.berlios.de/">http://tetgen.berlios.de/</a></li> <li>• TRIANGLE_FF: <b>Triangle</b> is a 2-D mesh generator, see site: <a href="http://www.cs.cmu.edu/~quake/triangle.html">http://www.cs.cmu.edu/~quake/triangle.html</a></li> </ul>
out	<i>mesh</i>	<b>Mesh</b> 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.

## Author

Rachid Touzani

## Copyright

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```
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>	<a href="#">Mesh</a> 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.

## Author

Rachid Touzani

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**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 <b>Easymesh</b> 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 <b>Easymesh</b> .
----	-------------	--

## 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>	<a href="#">Mesh</a> 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.

## Author

Rachid Touzani

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**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 <b>Gambit</b> neutral format.
out	<i>mesh</i>	<a href="#">Mesh</a> 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.

Author

Rachid Touzani

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**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 <b>Gmsh</b> format.
out	<i>mesh</i>	<a href="#">Mesh</a> 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.

Author

Rachid Touzani

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**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>	<b>Mesh</b> 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.

## Author

Rachid Touzani

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**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>	<b>Mesh</b> 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 ]

## Author

Rachid Touzani

## Copyright

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**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 <b>Tetgen</b> format.
out	<i>mesh</i>	<a href="#">Mesh</a> 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.

## Author

Rachid Touzani

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**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/](http://people.scs.fsu.edu/~burkardt/c_src/triangle/triangle.html/)

## Parameters

in	<i>file</i>	Name of a file written in the <b>Tetgen</b> format.
out	<i>mesh</i>	<a href="#">Mesh</a> 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.

## Author

Rachid Touzani

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**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>	<a href="#">Mesh</a> 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"> <li>• GMSH: Mesh generator and graphical postprocessor <b>Gmsh</b>: <a href="http://www.geuz.org/gmsh/">http://www.geuz.org/gmsh/</a></li> <li>• GNUPLOT: Well known graphics software: <a href="http://www.gnuplot.info/">http://www.gnuplot.info/</a></li> <li>• MATLAB: Matlab file: <a href="http://www.mathworks.com/products/matlab/">http://www.mathworks.com/products/matlab/</a></li> <li>• TECPLOT: Commercial graphics software: <a href="http://www.tecplot.com">http://www.tecplot.com</a></li> <li>• VTK: Graphics format for the free postprocessor <b>ParaView</b>: <a href="http://public.kitware.com/VTK/">http://public.kitware.com/VTK/</a></li> </ul>

## Author

Rachid Touzani

## Copyright

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**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 <b>Gmsh</b> format.
in	<i>mesh</i>	<a href="#">Mesh</a> instance to save.

## Author

Rachid Touzani

## Copyright

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**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 <b>Gnuplot</b> format.
in	<i>mesh</i>	<b>Mesh</b> instance to save.

## Author

Rachid Touzani

## Copyright

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**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 <b>Matlab</b> format.
in	<i>mesh</i>	<b>Mesh</b> instance to save.

## Author

Rachid Touzani

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**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 <b>Tecplot</b> format.
in	<i>mesh</i>	<a href="#">Mesh</a> instance to save.

## Author

Rachid Touzani

## Copyright

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**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 <b>VTK</b> format.
in	<i>mesh</i>	<a href="#">Mesh</a> instance to save.

## Author

Rachid Touzani

## Copyright

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**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>	<a href="#">Mesh</a> instance.
----	-------------	--------------------------------

## Author

Rachid Touzani

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**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 ditributed by Keith Vertanen ([vertankd@cda.mrs.umn.edu](mailto: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 <a href="#">Point</a> stucture.
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

## Author

Rachid Touzani

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**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.
----	-------------	--

Author

Rachid Touzani

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**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\_.

Author

Rachid Touzani

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**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)

Author

Rachid Touzani

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**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.

## Author

Rachid Touzani

## Copyright

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**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	<i>v</i>	Vector to clear
----	----------	-----------------

**void Clear ( Vect< T\_ > &*v* )**

Assign 0 to all entries of a vector.

Parameters

in	<i>v</i>	Vector to clear
----	----------	-----------------

**real\_t Nrm2 ( size\_t *n*, real\_t\* *x* )**

Return 2-norm of array *x*

Parameters

in	<i>n</i>	is Array length
in	<i>x</i>	Array to treat

**bool Equal ( real\_t *x*, real\_t *y*, real\_t *toler* = 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

## 5.18 Vector and Matrix

Vector and matrix 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\_ >  
Vect< T\_ > [operator\\*](#) (const BMatrix< T\_ > &A, const Vect< T\_ > &b)  
*Operator \* (Multiply vector by matrix and return resulting 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_>`  
`Vect< T_> operator* (const DMatrix< T_> &A, const Vect< T_> &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector).*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const DMatrix< T_> &a)`  
*Output matrix in output stream.*
- `template<class T_>`  
`Vect< T_> operator* (const DSMatrix< T_> &A, const Vect< T_> &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector).*
- `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_>`  
`Vect< T_ > operator* (const SkMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const SkMatrix< T_ > &a)`  
*Output matrix in output stream.*
- `template<class T_>`  
`Vect< T_ > operator* (const SkSMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const SkSMatrix< T_ > &a)`  
*Output matrix in output stream.*
- `template<class T_>`  
`Vect< T_ > operator* (const SpMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const SpMatrix< T_ > &A)`  
*Output matrix in output stream.*
- `template<class T_>`  
`Vect< T_ > operator* (const TrMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- `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)`

### 5.18.1 Detailed Description

Vector and matrix classes.

### 5.18.2 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](#)

### 5.18.3 Function Documentation

**Vect< T\_ > operator\* ( const BMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	<i>A</i>	<a href="#">BMatrix</a> instance to multiply by vector
in	<i>b</i>	<a href="#">Vect</a> instance

Returns

[Vect](#) instance containing  $A*b$

**BMatrix< T\_ > operator\* ( T\_ a, const BMatrix< T\_ > & A )**

Operator \* (Premultiplication of matrix by constant)

Returns

$a*A$

**Vect< T\_ > operator\* ( const DMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	<i>A</i>	<a href="#">DMatrix</a> instance to multiply by vector
in	<i>b</i>	<a href="#">Vect</a> instance

Returns

[Vect](#) instance containing  $A*b$

**`Vect< T_ > operator* ( const DSMatrix< T_ > & A, const Vect< T_ > & b )`**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	$A$	<a href="#">DSMatrix</a> instance to multiply by vector
in	$b$	<a href="#">Vect</a> instance

Returns

[Vect](#) instance containing  $A*b$

**`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 <a href="#">PETScMatrix</a> )
in	$x$	Vector to multiply by (Instance of class <a href="#">PETScVect</a> )

Returns

Vector product  $y = Ax$

**Vect< T\_ > operator\* ( const SkMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	$A$	<a href="#">SkMatrix</a> instance to multiply by vector
in	$b$	<a href="#">Vect</a> instance

Returns

[Vect](#) instance containing  $A*b$

Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const SkMatrix< T\_ > & a )**

Output matrix in output stream.

Author

Rachid Touzani

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Rachid Touzani

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**Vect< T\_ > operator\* ( const SkSMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	$A$	<a href="#">SkSMatrix</a> instance to multiply by vector
in	$b$	<a href="#">Vect</a> instance



## Returns

[Vect](#) instance containing  $A*b$

## Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const SkSMatrix< T\_ > & a )**

Output matrix in output stream.

## Author

Rachid Touzani

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**Vect< T\_ > operator\* ( const SpMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

## Parameters

in	$A$	<a href="#">SpMatrix</a> instance to multiply by vector
in	$b$	<a href="#">Vect</a> instance

## Returns

[Vect](#) instance containing  $A*b$

## Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const SpMatrix< T\_ > & A )**

Output matrix in output stream.

## Author

Rachid Touzani

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**Vect< T\_ > operator\* ( const TrMatrix< T\_ > & A, const Vect< T\_ > & b )**

Operator \* (Multiply vector by matrix and return resulting vector.

Parameters

in	<i>A</i>	TrMatrix instance to multiply by vector
in	<i>b</i>	Vect instance

Returns

Vect instance containing A\*b

Author

Rachid Touzani

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**TrMatrix< T\_ > operator\* ( T\_ a, const TrMatrix< T\_ > & A )**

Operator \* (Premultiplication of matrix by constant)

Returns

a\*A

Author

Rachid Touzani

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**ostream & operator<< ( ostream & s, const TrMatrix< T\_ > & a )**

Output matrix in output stream.

Author

Rachid Touzani

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**real\_t operator\* ( const vector< real\_t > & x, const vector< real\_t > & y )**

Operator \* (Dot product of 2 vector instances)

Returns

$x \cdot y$

#### 5.18.4 Friends

**ostream & operator<< ( ostream & s, const SpMatrix< TT\_ > & A ) [friend]**

Output matrix in output stream



# Chapter 6

## Namespace Documentation

### 6.1 OFELI Namespace Reference

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

#### Classes

- class [AbsEqua](#)  
*Mother abstract class to describe equation.*
- 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 [BiotSavart](#)  
*Class to compute the magnetic induction from the current density using the Biot-Savart formula.*
- class [BMatrix](#)  
*To handle band matrices.*
- class [Brick](#)  
*To store and treat a brick (parallelepiped) figure.*
- class [Circle](#)  
*To store and treat a circular figure.*
- 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 [DG](#)  
*Enables preliminary operations and utilities for the Discontinuous Galerkin method.*
- class [DMatrix](#)

- To handle dense matrices.*
- class [Domain](#)
  - To store and treat finite element geometric information.*
- class [DSMatrix](#)
  - To handle symmetric dense matrices.*
- class [EC2D1T3](#)
  - Eddy current problems in 2-D domains using solenoidal approximation.*
- class [EC2D2T3](#)
  - Eddy current problems in 2-D domains using transversal approximation.*
- class [Edge](#)
  - To describe an edge.*
- class [EdgeList](#)
  - Class to construct a list of edges having some common properties.*
- class [EigenProblemSolver](#)
  - 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.*
- 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 [Element](#)
  - To store and treat finite element geometric information.*
- class [ElementList](#)
  - Class to construct a list of elements having some common properties.*
- class [Ellipse](#)
  - To store and treat an ellipsoidal figure.*
- class [Equa\\_Electromagnetics](#)
  - Abstract class for Electromagnetics [Equation](#) classes.*
- class [Equa\\_Fluid](#)
  - Abstract class for Fluid Dynamics [Equation](#) classes.*
- class [Equa\\_Laplace](#)
  - Abstract class for classes about the Laplace equation.*
- class [Equa\\_Porous](#)
  - Abstract class for Porous Media Finite Element classes.*
- class [Equa\\_Solid](#)
  - Abstract class for Solid Mechanics Finite Element classes.*
- class [Equa\\_Therm](#)
  - Abstract class for Heat transfer Finite Element classes.*
- class [Equation](#)
  - Abstract class for all equation classes.*
- class [Estimator](#)

- To calculate an a posteriori estimator of the solution.*

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

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

  - class [Figure](#)
- To store and treat a figure (or shape) information.*

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

  - class [Gauss](#)
- Calculate data for Gauss integration.*

  - class [Grid](#)
- To manipulate structured grids.*

  - class [HelmholtzBT3](#)
- Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.*

  - class [Hexa8](#)
- Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation.*

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

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

  - class [Iter](#)
- Class to drive an iterative process.*

  - 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 [LaplaceDG2DP1](#)

- To build and solve the linear system for the Poisson problem using the [DG](#)  $P_1$  2-D triangle element.

  - 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 [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 [LinearSolver](#)
- Class to solve systems of linear equations by iterative methods.

  - class [LocalMatrix](#)
- Handles small size matrices like element matrices, with a priori known size.

  - class [LocalVect](#)
- Handles small size vectors like element vectors.

  - 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 [Matrix](#)
- Virtual class to handle matrices for all storage formats.

  - class [Mesh](#)
- To store and manipulate finite element meshes.

  - class [MeshAdapt](#)
- To adapt mesh in function of given solution.

  - 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.

  - class [MyNLAS](#)
- Abstract class to define by user specified function.

  - class [MyOpt](#)
- Abstract class to define by user specified optimization function.

  - class [NLASSolver](#)
- To solve a system of nonlinear algebraic equations of the form  $f(u) = 0$ .

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

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

  - 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 [ODESolver](#)  
*To solve a system of ordinary differential equations.*
- class [OFELIException](#)  
*To handle exceptions in [OFELI](#).*
- class [OptSolver](#)  
*To solve an optimization problem with bound constraints.*
- class [Partition](#)  
*To partition a finite element mesh into balanced submeshes.*
- 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 [PETScMatrix](#)  
*To handle matrices in sparse storage format using the Petsc library.*
- class [PETScVect](#)  
*To handle general purpose vectors using Petsc.*
- class [PETScWrapper](#)  
*This class is a wrapper to be used when the library Petsc is installed and used with [OFELI](#).*
- class [PhaseChange](#)  
*This class enables defining phase change laws for a given material.*
- class [Point](#)  
*Defines a point with arbitrary type coordinates.*
- class [Point2D](#)  
*Defines a 2-D point with arbitrary type coordinates.*
- class [Polygon](#)  
*To store and treat a polygonal figure.*
- class [Prec](#)  
*To set a preconditioner.*
- 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 [Quad4](#)  
*Defines a 4-node quadrilateral finite element using  $Q_1$  isoparametric interpolation.*
- class [Reconstruction](#)  
*To perform various reconstruction operations.*
- class [Rectangle](#)  
*To store and treat a rectangular figure.*
- class [Side](#)  
*To store and treat finite element sides (edges in 2-D or faces in 3-D)*
- class [SideList](#)  
*Class to construct a list of sides having some common properties.*
- class [SkMatrix](#)  
*To handle square matrices in skyline storage format.*
- class [SkSMatrix](#)  
*To handle symmetric matrices in skyline storage format.*

- class [Sphere](#)  
*To store and treat a sphere.*
- class [SpMatrix](#)  
*To handle matrices in sparse storage format.*
- class [SteklovPoincare2DBE](#)  
*Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.*
- class [Tabulation](#)  
*To read and manipulate tabulated functions.*
- class [Tetra4](#)  
*Defines a three-dimensional 4-node tetrahedral finite element using  $P_1$  interpolation.*
- class [Timer](#)  
*To handle elapsed time counting.*
- 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 [TINS2DT3S](#)  
*Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*
- class [TINS3DT4S](#)  
*Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.*
- class [Triang3](#)  
*Defines a 3-Node ( $P_1$ ) triangle.*
- class [Triang6S](#)  
*Defines a 6-Node straight triangular finite element using  $P_2$  interpolation.*
- class [triangle](#)  
*Defines a triangle. The reference element is the rectangle triangle with two unit edges.*
- class [Triangle](#)  
*To store and treat a triangle.*
- class [TrMatrix](#)  
*To handle tridiagonal matrices.*
- class [UserData](#)  
*Abstract class to define by user various problem data.*
- class [Vect](#)  
*To handle general purpose vectors.*
- class [WaterPorous2D](#)  
*To solve water flow equations in porous media (1-D)*

## Enumerations

## 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 saveGnuplot (Mesh &mesh, string input_file, string output_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 saveTecplot (Mesh &mesh, string input_file, string output_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 saveVTK (Mesh &mesh, string input_file, string output_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.*
- `void saveGmsh (Mesh &mesh, string input_file, string output_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 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.*
- `template<class T_>`  
`Vect< T_ > operator* (const BMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting 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_>`  
`Vect< T_ > operator* (const DMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector).*
- `template<class T_>`  
`ostream & operator<< (ostream &s, const DMatrix< T_ > &a)`  
*Output matrix in output stream.*
- `template<class T_>`  
`Vect< T_ > operator* (const DSMatrix< T_ > &A, const Vect< T_ > &b)`  
*Operator \* (Multiply vector by matrix and return resulting vector).*

- `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=OFF←  
 LL.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\_ >  
**Vect**< T\_ > **operator\*** (const **SkMatrix**< T\_ > &A, const **Vect**< T\_ > &b)  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- template<class T\_ >  
**ostream & operator<<** (ostream &s, const **SkMatrix**< T\_ > &a)  
*Output matrix in output stream.*
- template<class T\_ >  
**Vect**< T\_ > **operator\*** (const **SkSMatrix**< T\_ > &A, const **Vect**< T\_ > &b)  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- template<class T\_ >  
**ostream & operator<<** (ostream &s, const **SkSMatrix**< T\_ > &a)  
*Output matrix in output stream.*
- template<class T\_ >  
**Vect**< T\_ > **operator\*** (const **SpMatrix**< T\_ > &A, const **Vect**< T\_ > &b)  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- template<class T\_ >  
**ostream & operator<<** (ostream &s, const **SpMatrix**< T\_ > &A)  
*Output matrix in output stream.*
- template<class T\_ >  
**Vect**< T\_ > **operator\*** (const **TrMatrix**< T\_ > &A, const **Vect**< T\_ > &b)  
*Operator \* (Multiply vector by matrix and return resulting vector.*
- 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 union 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 &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.*
- `ostream & operator<< (ostream &s, const NLASSolver &nl)`  
*Output nonlinear system information.*
- `ostream & operator<< (ostream &s, const ODESolver &de)`  
*Output differential system information.*
- `ostream & operator<< (ostream &s, const OptSolver &os)`  
*Output differential system information.*
- `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 Dot (const vector< real_t > &x, const vector< real_t > &y)`  
*Return dot product of vectors  $x$  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 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  $y$*
- `real_t exprep (real_t x)`  
*Compute the exponential function with avoiding over and underflows.*
- `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=OFELI.EPSMCH)`  
*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.*

## 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.



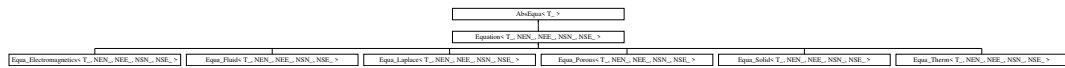
# Chapter 7

## 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.*
- 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.*
- void [setMatrixType](#) (int t)  
*Choose type of matrix.*
- int [solveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int [solveLinearSystem](#) ([Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system with given right-hand side.*

#### 7.1.1 Detailed Description

```
template<class T_>
class OFELI::AbsEqua< T_ >
```

Mother abstract class to describe equation.

## Template Parameters

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

## Author

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## 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>

**void setMatrixType ( int *t* )**

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

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

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > & *b*, Vect< T\_ > & *x* )**

Solve the linear system with given right-hand side.

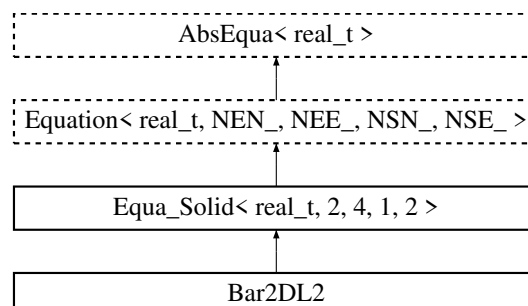
Parameters

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**< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
  - void **updateBC** (const **Vect**< real\_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**< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
  - void **ElementNodeVector** (const **Vect**< real\_t > &b, **LocalVect**< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
  - void **ElementNodeVector** (const **Vect**< real\_t > &b, **LocalVect**< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
  - void **ElementNodeVectorSingleDOF** (const **Vect**< real\_t > &b, **LocalVect**< real\_t, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
  - void **ElementSideVector** (const **Vect**< real\_t > &b, **LocalVect**< real\_t, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
  - void **ElementVector** (const **Vect**< real\_t > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
  - void **SideVector** (const **Vect**< real\_t > &b)  
*Localize Side Vector.*
  - void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
  - void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
  - void **ElementAssembly** (**Matrix**< real\_t > \*A)  
*Assemble element matrix into global one.*
  - void **ElementAssembly** (**PETScMatrix**< real\_t > &A)  
*Assemble element matrix into global one.*
  - void **ElementAssembly** (**PETScVect**< real\_t > &b)  
*Assemble element right-hand side vector into global one.*
  - void **ElementAssembly** (**BMatrix**< real\_t > &A)  
*Assemble element matrix into global one.*

- void [ElementAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SpMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (TrMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (Vect< real.t > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) (PETScMatrix< real.t > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) (PETScVect< real.t > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) (Matrix< real.t > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SpMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (Vect< real.t > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) (Matrix< real.t > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SpMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (TrMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const Vect< real.t > &x, Vect< real.t > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const Vect< real.t > &x, Vect< real.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< real.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< real_t > &getLinearSolver` ()  
*Return reference to linear solver instance.*
- void `setSolver` (`Iteration` ls, `Preconditioner` pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- void `setMatrixType` (int t)  
*Choose type of matrix.*
- int `solveLinearSystem` (`Matrix< real_t > *A`, `Vect< real_t > &b`, `Vect< real_t > &x`)  
*Solve the linear system with given matrix and right-hand side.*
- int `solveLinearSystem` (`Vect< real_t > &b`, `Vect< real_t > &x`)  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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

in	<i>el</i>	Pointer to <a href="#">Element</a>
in	<i>section</i>	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

in	<i>coef</i>	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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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	<i>u</i>	Vect instance containing displacements at nodes
in	<i>s</i>	Vect 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	<i>K</i>	Stiffness matrix
in	<i>M</i>	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	<i>K</i>	Stiffness matrix
in	<i>M</i>	Vector containing diagonal mass matrix

**void updateBC ( const Element &el, const Vect< real.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< real.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< real.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 Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & *b*, LocalVect< real\_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< real\_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< real\_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< real.t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real.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< real\_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< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real.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< real\_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< real\_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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkSMatrix instance
----	-----	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< real.t > & x, Vect< real.t > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

## Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

## Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

## 7.2.4 Member Data Documentation

**LocalVect<real\_t,NEE\_> ePrev** [inherited]

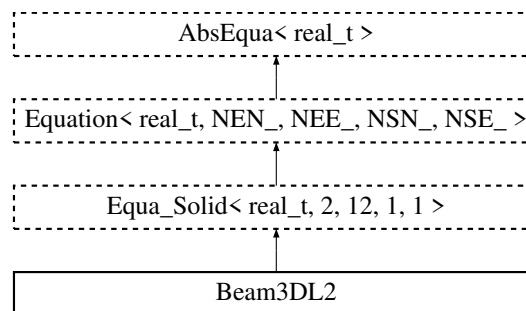
LocalVect instance containing local vector associated to current element.

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](#)< [real\\_t](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [real\\_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](#)< [real\\_t](#) > &b)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void [SideVector](#) (const [Vect](#)< [real\\_t](#) > &b)  
*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)



- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (Vect< real.t > &v)
- Assemble element vector into global one.*
  - void [SideAssembly](#) (PETScMatrix< real.t > &A)
- Assemble side matrix into global one.*
  - void [SideAssembly](#) (PETScVect< real.t > &b)
- Assemble side right-hand side vector into global one.*
  - void [SideAssembly](#) (Matrix< real.t > \*A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SkMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SkMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SpMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (Vect< real.t > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) (Matrix< real.t > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const Vect< real.t > &x, Vect< real.t > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const Vect< real.t > &x, Vect< real.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< real.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**< **real.t** > & **getLinearSolver** ()
- *Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)
- *Choose solver for the linear system.*
- void **setMatrixType** (int t)
- *Choose type of matrix.*
- int **solveLinearSystem** (**Matrix**< **real.t** > \*A, **Vect**< **real.t** > &b, **Vect**< **real.t** > &x)
- *Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (**Vect**< **real.t** > &b, **Vect**< **real.t** > &x)
- *Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.3.1 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 <b>Element</b>
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 <b>Element</b>
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>	<b>Mesh</b> instance
in	<i>u</i>	Vector containing the solution vector

Parameters

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< real\_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< real\_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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_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 dof 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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---



**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real\_t > & v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.3.4 Member Data Documentation

**LocalVect<real.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.

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### 7.4.2 Constructor & Destructor Documentation

**BiotSavart ( Mesh & ms )**

Constructor using mesh data.

Parameters

in	ms	<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

in	ms	<a href="#">Mesh</a> instance
in	J	Sidewise vector of current density (J is a real valued vector), in the case of a surface supported current



## Parameters

in	$B$	Nodewise vector that contains, once the member function run is used, the magnetic induction
in	$code$	Only sides with given $code$ 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

in	$ms$	<a href="#">Mesh</a> instance
in	$J$	Sidewise vector of current density ( $J$ is a complex valued vector), in the case of a surface supported current
in	$B$	Nodewise vector that contains, once the member function run is used, the magnetic induction
in	$code$	Only sides with given $code$ 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

in	$J$	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

in	$J$	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 ( )**

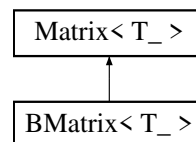
Run the calculation by the Biot-Savart formula.

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 **Axpy** (T\_ a, const **BMatrix**< T\_ > &x)  
*Add to matrix the product of a matrix by a scalar.*
- void **Axpy** (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)  
*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.*
- virtual void **reset** ()  
*Set matrix to 0 and reset factorization parameter.*
- 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).*
- `virtual void clear ()`  
*Set all matrix entries to zero*
- `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

$T_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
$_{\leftrightarrow}$	

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### 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

in	<i>size</i>	Number of rows and columns
in	<i>ld</i>	Number of lower co-diagonals (must be > 0)
in	<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

in	<i>size</i>	Number of rows and columns
in	<i>ld</i>	Number of lower co-diagonals (must be > 0)
in	<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

in	<i>a</i>	Scalar to premultiply
in	<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

in	<i>a</i>	Scalar to premultiply
in	<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
----	----------	-----------



Parameters

in	$j$	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	$b$	<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* )** [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	<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.

Implements [Matrix< T\\_ >](#).

**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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 **setPenal(..)**.

Parameters

in,out	<i>b</i>	<a href="#">Vect</a> instance that contains right-hand side.
--------	----------	--

## Parameters

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

<code>in</code>	<code>dof</code>	Label of the concerned degree of freedom (DOF).
<code>in,out</code>	<code>b</code>	<a href="#">Vect</a> instance that contains right-hand side.
<code>in</code>	<code>u</code>	<a href="#">Vect</a> instance that contains imposed values at DOFs where they are to be imposed.
<code>in</code>	<code>flag</code>	Parameter to determine whether only the right-hand side is to be modified ( <code>dof&gt;0</code> ) or both matrix and right-hand side ( <code>dof=0</code> , 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

<code>in,out</code>	<code>b</code>	<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

<code>in</code>	<code>b</code>	<a href="#">Vect</a> instance that contains right-hand side
<code>out</code>	<code>x</code>	<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

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]

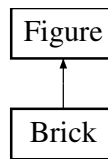
Operator -=.

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>	Point<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	$p$	<a href="#">Point</a> for which distance is computed
in	$a$	First vertex of line
in	$b$	Second vertex of line

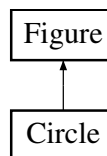
Returns

Signed distance

## 7.7 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	<i>c</i>	Coordinates of center of circle
in	<i>r</i>	Radius
in	<i>code</i>	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	<i>p</i>	Point<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	<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>	Point for which distance is computed
in	<i>a</i>	First vertex of line
in	<i>b</i>	Second vertex of line

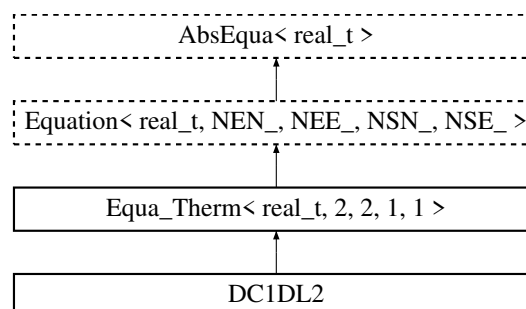
## Returns

Signed distance

## 7.8 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 (Mesh &ms)`
- `~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](#) &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](#)< [real\\_t](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [real\\_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](#)< [real\\_t](#) > &b)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void [SideVector](#) (const [Vect](#)< [real\\_t](#) > &b)  
*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()  
*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()  
*Localize coordinates of side nodes.*

- void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< [real\\_t](#) > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< [real\\_t](#) > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_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< real_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< real_t > & getLinearSolver ()`  
*Return reference to linear solver instance.*
- `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`  
*Choose solver for the linear system.*
- `void setMatrixType (int t)`  
*Choose type of matrix.*
- `int solveLinearSystem (Matrix< real_t > *A, Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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] Vect 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>	Vect 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>

#### DC1DL2 ( Mesh & *ms* )

Constructor using mesh instance

Parameters

in	<i>ms</i>	Mesh instance
----	-----------	---------------



### 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

in	<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

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

in	<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

in	<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

in	<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

in	<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

in	<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

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 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, 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

in	<i>v</i>	Velocity vector
in	<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

in	<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.
----	----------	--

## Parameters

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

in	<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>
in	<i>u</i>	Vector containing input data

**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

in	<i>s</i>	Reference to used TimeStepping instance
----	----------	---

**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< real.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< real.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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real\_t > & v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > & A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > & b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an <code>SkSMatrix</code> instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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



**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

## 7.8.4 Member Data Documentation

**LocalVect<real.t,NEE\_> ePrev** [inherited]

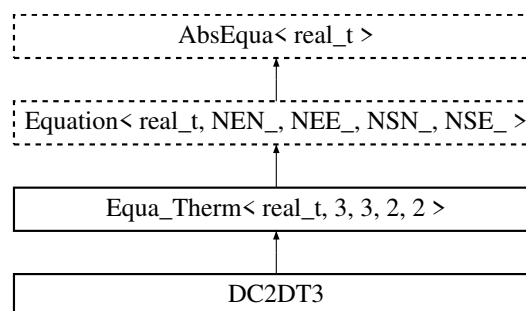
LocalVect instance containing local vector associated to current element.

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**< **real\_t** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< **real\_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< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const Vect< real\_t > &b, LocalVect< real\_t, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const Vect< real\_t > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const Vect< real\_t > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (Matrix< real\_t > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (PETScMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (PETScVect< real\_t > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (BMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SkSMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SkMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SpMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (TrMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (Vect< real\_t > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (PETScMatrix< real\_t > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (PETScVect< real\_t > &b)  
*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (Matrix< real\_t > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (SkSMatrix< real\_t > &A)  
*Assemble side (edge or face) matrix into global one.*

- void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< [real\\_t](#) > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_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](#)< [real\\_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](#)< [real\\_t](#) > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- void [setMatrixType](#) (int t)  
*Choose type of matrix.*
- int [solveLinearSystem](#) ([Matrix](#)< [real\\_t](#) > \*A, [Vect](#)< [real\\_t](#) > &b, [Vect](#)< [real\\_t](#) > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int [solveLinearSystem](#) ([Vect](#)< [real\\_t](#) > &b, [Vect](#)< [real\\_t](#) > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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.*

### 7.9.1 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

in	ms	<code>Mesh</code> instance
----	----	----------------------------

**DC2DT3 ( Mesh & ms, Vect< real\_t > & u )**

Constructor using `Mesh` and initial condition.

Parameters

in	ms	<code>Mesh</code> instance
in	u	<code>Vect</code> 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

in	<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

in	<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

in	<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

in	<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

in	<i>diff</i>	Diffusion matrix (class <a href="#">LocalMatrix</a> ).
in	<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

in	<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	<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 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, 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	<i>v</i>	Velocity vector
in	<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

in	<i>coef</i>	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	<i>coef</i>	Coefficient of exchange
in	<i>T</i>	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	<i>sigma</i>	Vect instance containing electric conductivity (elementwise)
in	<i>psi</i>	Vect 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.

**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 ( 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< real.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< real.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< real.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 Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & *b*, LocalVect< real\_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< real\_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< real\_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< real.t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real.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< real\_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< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.t > &  $A$  )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > & *b* )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real\_t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SkMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( SpMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGELEMENTAssembly ( TrMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

## Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

## Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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<real\_t,NEE\_> ePrev** [inherited]

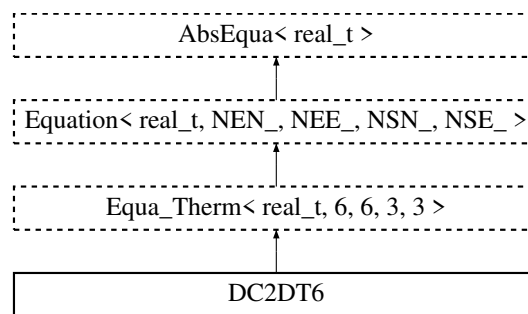
LocalVect instance containing local vector associated to current element.

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 (Mesh &ms)**  
*Constructor using Mesh data.*
- **~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** &**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**< **real\_t** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< **real\_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**< **real\_t** > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< **real\_t** > &b, **LocalVect**< **real\_t**, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< **real\_t** > &b, **LocalVect**< **real\_t**, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< **real\_t** > &b, **LocalVect**< **real\_t**, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const **Vect**< **real\_t** > &b, **LocalVect**< **real\_t**, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const **Vect**< **real\_t** > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const **Vect**< **real\_t** > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< **real\_t** > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< **real\_t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< **real\_t** > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< **real\_t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< **real\_t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkMatrix**< **real\_t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SpMatrix**< **real\_t** > &A)

- Assemble element matrix into global one.*
  - void `ElementAssembly` (`TrMatrix`< `real.t` > &`A`)
- Assemble element matrix into global one.*
  - void `ElementAssembly` (`Vect`< `real.t` > &`v`)
- Assemble element vector into global one.*
  - void `SideAssembly` (`PETScMatrix`< `real.t` > &`A`)
- Assemble side matrix into global one.*
  - void `SideAssembly` (`PETScVect`< `real.t` > &`b`)
- Assemble side right-hand side vector into global one.*
  - void `SideAssembly` (`Matrix`< `real.t` > \*`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SkSMatrix`< `real.t` > &`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SkMatrix`< `real.t` > &`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SpMatrix`< `real.t` > &`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`Vect`< `real.t` > &`v`)
- Assemble side (edge or face) vector into global one.*
  - void `DGElementAssembly` (`Matrix`< `real.t` > \*`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SkSMatrix`< `real.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SkMatrix`< `real.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SpMatrix`< `real.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`TrMatrix`< `real.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `AxbAssembly` (const `Element` &`el`, const `Vect`< `real.t` > &`x`, `Vect`< `real.t` > &`b`)
- Assemble product of element matrix by element vector into global vector.*
  - void `AxbAssembly` (const `Side` &`sd`, const `Vect`< `real.t` > &`x`, `Vect`< `real.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`< `real.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`< `real.t` > & `getLinearSolver` ()

- *Return reference to linear solver instance.*
- void `setSolver` (`Iteration` ls, `Preconditioner` pc=`IDENT_PREC`)  
*Choose solver for the linear system.*
- void `setMatrixType` (int t)  
*Choose type of matrix.*
- int `solveLinearSystem` (`Matrix`< `real.t` > \*A, `Vect`< `real.t` > &b, `Vect`< `real.t` > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int `solveLinearSystem` (`Vect`< `real.t` > &b, `Vect`< `real.t` > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix`< `real.t`, `NEE_`, `NEE_` > `eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix`< `real.t`, `NSE_`, `NSE_` > `sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect`< `real.t`, `NEE_` > `ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect`< `real.t`, `NEE_` > `eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect`< `real.t`, `NEE_` > `eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect`< `real.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

in	<i>el</i>	Pointer to element.
----	-----------	---------------------

**DC2DT6 ( const Side \* *sd* )**

Constructor for a boundary side.

Parameters

in	<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

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].

**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

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: 1]
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>

**DC2DT6 ( 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.
----	-----------	------------------

Parameters

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].

**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>

**DC2DT6 ( Mesh & *ms* )**

Constructor using [Mesh](#) data.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

### 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

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< real\_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< real\_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< real\_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 <code>Element</code> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_t, NSE\_ > & be )**  
[inherited]

Localize Element Vector from a Vect instance.

Parameters

in	<i>b</i>	Global vector to be localized.
----	----------	--------------------------------

## Parameters

out	<i>be</i>	Local vector, the length of which is
-----	-----------	--------------------------------------

**void ElementVector ( const Vect< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>A</code>	Global matrix stored as a BMatrix instance
----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--



## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real.t > & A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real.t > & b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkSMatrix instance
----	---	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real\_t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.10.4 Member Data Documentation

**LocalVect<real.t,NEE\_> ePrev** [inherited]

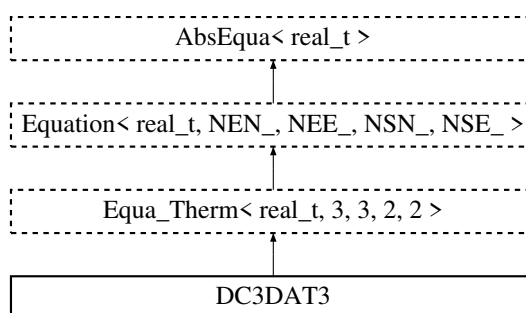
LocalVect instance containing local vector associated to current element.

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** (**Mesh** &ms)  
*Constructor using **Mesh** data.*
- **~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`< `real.t` > &`bc`)



- Update Right-Hand side by taking into account essential boundary conditions.*

  - void `updateBC` (const `Vect< real_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< real_t >` &b)
- Localize Element Vector from a Vect instance.*

  - void `ElementNodeVector` (const `Vect< real_t >` &b, `LocalVect< real_t, NEE_ >` &be)
- Localize Element Vector from a Vect instance.*

  - void `ElementNodeVector` (const `Vect< real_t >` &b, `LocalVect< real_t, NEN_ >` &be, int dof)
- Localize Element Vector from a Vect instance.*

  - void `ElementNodeVectorSingleDOF` (const `Vect< real_t >` &b, `LocalVect< real_t, NEN_ >` &be)
- Localize Element Vector from a Vect instance.*

  - void `ElementSideVector` (const `Vect< real_t >` &b, `LocalVect< real_t, NSE_ >` &be)
- Localize Element Vector from a Vect instance.*

  - void `ElementVector` (const `Vect< real_t >` &b, int dof\_type=NODE.FIELD, int flag=0)
- Localize Element Vector.*

  - void `SideVector` (const `Vect< real_t >` &b)
- Localize Side Vector.*

  - void `ElementNodeCoordinates` ()
- Localize coordinates of element nodes.*

  - void `SideNodeCoordinates` ()
- Localize coordinates of side nodes.*

  - void `ElementAssembly` (`Matrix< real_t >` \*A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`PETScMatrix< real_t >` &A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`PETScVect< real_t >` &b)
- Assemble element right-hand side vector into global one.*

  - void `ElementAssembly` (`BMatrix< real_t >` &A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`SkSMatrix< real_t >` &A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`SkMatrix< real_t >` &A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`SpMatrix< real_t >` &A)
- Assemble element matrix into global one.*

  - void `ElementAssembly` (`TrMatrix< real_t >` &A)
- Assemble element vector into global one.*

  - void `ElementAssembly` (`Vect< real_t >` &v)
- Assemble side matrix into global one.*

  - void `SideAssembly` (`PETScMatrix< real_t >` &A)
- Assemble side right-hand side vector into global one.*

  - void `SideAssembly` (`PETScVect< real_t >` &b)
- Assemble side right-hand side vector into global one.*

  - void `SideAssembly` (`Matrix< real_t >` \*A)

- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([Vect](#)< [real\\_t](#) > &[v](#))
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*[A](#))
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &[A](#))
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &[el](#), const [Vect](#)< [real\\_t](#) > &[x](#), [Vect](#)< [real\\_t](#) > &[b](#))
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &[sd](#), const [Vect](#)< [real\\_t](#) > &[x](#), [Vect](#)< [real\\_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](#)< [real\\_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](#)< [real\\_t](#) > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
  - void [setSolver](#) ([Iteration](#) [ls](#), [Preconditioner](#) [pc](#)=[IDENT\\_PREC](#))
- Choose solver for the linear system.*
  - void [setMatrixType](#) (int [t](#))
- Choose type of matrix.*
  - int [solveLinearSystem](#) ([Matrix](#)< [real\\_t](#) > \*[A](#), [Vect](#)< [real\\_t](#) > &[b](#), [Vect](#)< [real\\_t](#) > &[x](#))
- Solve the linear system with given matrix and right-hand side.*
  - int [solveLinearSystem](#) ([Vect](#)< [real\\_t](#) > &[b](#), [Vect](#)< [real\\_t](#) > &[x](#))
- Solve the linear system with given right-hand side.*

## Public Attributes

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

in	el	Pointer to element.
----	----	---------------------

**DC3DAT3** ( const **Side** \* sd )

Constructor for a boundary side.

Parameters

in	<i>sd</i>	Pointer to side.
----	-----------	------------------

**DC3DAT3 ( 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]

**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

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 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>

**DC3DAT3 ( *Mesh* & *ms* )**

Constructor using [Mesh](#) data.

## Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

**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

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

in	<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

in	<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

in	<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

in	<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

in	<i>diff</i>	Instance of class <a href="#">DMatrix</a> containing diffusivity matrix
in	<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

in	<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

in	<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

in	<i>b</i>	Local vector (of size 3) 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 BoundaryRHS ( *real.t flux* )**

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

Parameters

in	<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

in	<i>sf</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 >](#).

**Point<real.t>& Grad ( const Vect< real.t > & *u* )**

Return gradient of a vector in element.

## Parameters

in	<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 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

in	<i>s</i>	Reference to used TimeStepping instance
----	----------	---

**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< real\_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< real\_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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an <code>SkSMatrix</code> instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--



## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.11.4 Member Data Documentation

**LocalVect<real.t,NEE\_> ePrev** [inherited]

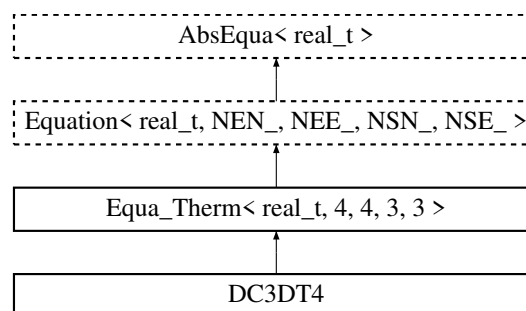
LocalVect instance containing local vector associated to current element.

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](#) ([Mesh](#) &ms)  
*Constructor using [Mesh](#) data.*
- [~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< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const Vect< real\_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< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be)

- Localize Element Vector from a Vect instance.*

  - void **ElementSideVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, NSE\_ > &be)

*Localize Element Vector from a Vect instance.*

  - void **ElementVector** (const **Vect**< **real.t** > &b, int dof.type=NODE.FIELD, int flag=0)

*Localize Element Vector.*

  - void **SideVector** (const **Vect**< **real.t** > &b)

*Localize Side Vector.*

  - void **ElementNodeCoordinates** ()

*Localize coordinates of element nodes.*

  - void **SideNodeCoordinates** ()

*Localize coordinates of side nodes.*

  - void **ElementAssembly** (**Matrix**< **real.t** > \*A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**PETScMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**PETScVect**< **real.t** > &b)

*Assemble element right-hand side vector into global one.*

  - void **ElementAssembly** (**BMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SkSMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SkMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SpMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**TrMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**Vect**< **real.t** > &v)

*Assemble element vector into global one.*

  - void **SideAssembly** (**PETScMatrix**< **real.t** > &A)

*Assemble side matrix into global one.*

  - void **SideAssembly** (**PETScVect**< **real.t** > &b)

*Assemble side right-hand side vector into global one.*

  - void **SideAssembly** (**Matrix**< **real.t** > \*A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SkSMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SkMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SpMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**Vect**< **real.t** > &v)

*Assemble side (edge or face) vector into global one.*

  - void **DGElementAssembly** (**Matrix**< **real.t** > \*A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void **DGElementAssembly** (**SkSMatrix**< **real.t** > &A)

- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)
- *Assemble element matrix into global one for the Discontinuous Galerkin approximation.*  
void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)
- *Assemble product of element matrix by element vector into global vector.*  
void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_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](#)< [real\\_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](#)< [real\\_t](#) > & [getLinearSolver](#) ()  
*Return reference to linear solver instance.*
- void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=[IDENT\\_PREC](#))  
*Choose solver for the linear system.*
- void [setMatrixType](#) (int t)  
*Choose type of matrix.*
- int [solveLinearSystem](#) ([Matrix](#)< [real\\_t](#) > \*A, [Vect](#)< [real\\_t](#) > &b, [Vect](#)< [real\\_t](#) > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int [solveLinearSystem](#) ([Vect](#)< [real\\_t](#) > &b, [Vect](#)< [real\\_t](#) > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

- [LocalMatrix](#)< [real\\_t](#), [NEE\\_](#), [NEE\\_](#) > [eMat](#)  
*LocalMatrix instance containing local matrix associated to current element.*
- [LocalMatrix](#)< [real\\_t](#), [NSE\\_](#), [NSE\\_](#) > [sMat](#)  
*LocalMatrix instance containing local matrix associated to current side.*
- [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > [ePrev](#)  
*LocalVect instance containing local vector associated to current element.*
- [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > [eRHS](#)  
*LocalVect instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > [eRes](#)  
*LocalVect instance containing local residual vector associated to current element.*
- [LocalVect](#)< [real\\_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	<i>el</i>	Pointer to element.
----	-----------	---------------------

#### DC3DT4 ( const Side \* sd )

Constructor for a boundary side.

Parameters

<i>sd</i>	[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	<i>el</i>	Pointer to element.
in	<i>u</i>	<code>Vect</code> instance that contains solution at previous time step.
in	<i>time</i>	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>

**DC3DT4 ( Mesh & *ms* )**

Constructor using [Mesh](#) data.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

**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

in	<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

in	<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

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

in	<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

in	<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

in	<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

in	<i>diff</i>	Diffusion matrix (class <a href="#">DMatrix</a> ).
in	<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

in	<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

in	<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

in	<i>v</i>	Constant velocity vector
in	<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

in	<i>v</i>	Velocity vector.
in	<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

in	<i>v</i>	Velocity vector.
in	<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

in	<i>ud</i>	Instance of <a href="#">UserData</a> or of an inherited class. Contains a member function that provides body source.
----	-----------	--

## Parameters

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 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	coef	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

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< real\_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< real\_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>
----	-----------------	--



## Parameters

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. <i>dof</i> is handled in the system</li> </ul>
----	------------	---

**void LocalNodeVector ( Vect< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real\_t > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an <code>SkSMatrix</code> instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--



## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.12.4 Member Data Documentation

**LocalVect<real.t,NEE\_> ePrev** [inherited]

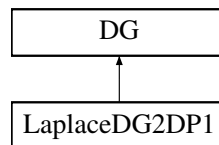
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.13 DG Class Reference

Enables preliminary operations and utilities for the Discontinuous Galerkin method.

Inheritance diagram for DG:



### Public Member Functions

- **DG** (**Mesh** &ms, size.t degree=1)  
*Constructor with mesh and degree of the method.*
- **~DG** ()  
*Destructor.*
- int **setGraph** ()  
*Set matrix graph.*

### 7.13.1 Detailed Description

Enables preliminary operations and utilities for the Discontinuous Galerkin method.

Author

Rachid Touzani

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### 7.13.2 Constructor & Destructor Documentation

DG ( Mesh & *ms*, size\_t *degree* = 1 )

Constructor with mesh and degree of the method.

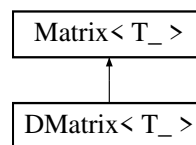
Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in	<i>degree</i>	Polynomial degree of the <a href="#">DG</a> method [Default: 1]

## 7.14 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](#) ([Mesh](#) &mesh, size\_t dof=0, int is\_diagonal=false)  
*Constructor using mesh to initialize structure of matrix.*
- [~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 **reset** ()  
*Set matrix to 0 and reset factorization parameter.*
- void **setRow** (size\_t i, const **Vect**< T\_ > &v)  
*Copy a given vector to a prescribed row in the matrix.*
- void **setColumn** (size\_t j, 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).*
- `virtual void clear ()`  
*brief Set all matrix entries to zero*
- `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 -=.*

### 7.14.1 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

$T_{\leftrightarrow}$ $_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
---	---

## Author

Rachid Touzani

## Copyright

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## 7.14.2 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

in	$v$	Vector to copy
----	-----	----------------

**DMatrix ( const DMatrix< T\_ > & m )**

Copy Constructor.

## Parameters

in	$m$	Matrix to copy
----	-----	----------------

**DMatrix ( Mesh & mesh, size\_t dof = 0, int is\_diagonal = false )**

Constructor using mesh to initialize 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. 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.

### 7.14.3 Member Function Documentation

**void setDiag ( const T\_ & a )**

Set matrix as diagonal and assign its diagonal entries as a constant.

Parameters

in	<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

in	<i>d</i>	Vector entries to assign to matrix diagonal entries
----	----------	---

**void setSize ( size\_t size )**

Set size (number of rows) of matrix.

Parameters

in	<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

in	<i>nr</i>	Number of rows.
in	<i>nc</i>	Number of columns.

**void getColumn ( size\_t *j*, Vect< T\_ > & *v* ) const**Get *j*-th column vector.

Parameters

in	<i>j</i>	Index of column to extract
out	<i>v</i>	Reference to Vect 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

in	<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

in	<i>i</i>	Index of row to extract
out	<i>v</i>	Reference to Vect 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 a( <i>i</i> , <i>j</i> ).

Implements [Matrix< T\\_ >](#).

**void reset ( )** [virtual]

Set matrix to 0 and reset factorization parameter.

## Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented from [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 *j*, 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	<i>x</i>	Vector to add to <i>y</i>
in,out	<i>y</i>	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	<i>x</i>	Vector to add to <i>y</i>
out	<i>y</i>	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	<i>x</i>	Vector to add to <i>y</i>
in,out	<i>y</i>	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>i</i>	row index
in	<i>j</i>	column index
in	<i>val</i>	Constant to add

Implements [Matrix< T\\_ >](#).**void Axy ( T\_ *a*, const DMatrix< 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\\_ >](#).**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  $Q_j = 1 - u_j u_j / c_j$ . 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>i</i>	row index
in	<i>j</i>	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* )** [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	<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.

Implements [Matrix< T\\_ >](#).

**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	<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.

**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 `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 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 homogeneous (=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>	Vect 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 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>	Vect instance that contains right-hand side.
in	<i>u</i>	Vect 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) 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.

## 7.15 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` ()  
*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 `insertVertex` (real\_t x, real\_t y, real\_t z, real\_t h, int code)  
*Insert a vertex (3-D case)*
- void `insertLine` (size\_t n1, size\_t n2, int c)  
*Insert a straight line.*
- 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 c)  
*Insert a circular arc.*
- 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.*
- void `setNbDOF` (int nb\_dof)  
*Set Number of degrees of freedom per node.*
- `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.*
- void `setOutputFile` (string file)  
*Define output mesh file.*



### 7.15.1 Detailed Description

To store and treat finite element geometric information.

This class is essentially useful to construct data for mesh generators.

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### 7.15.2 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

in	file	Input file in the XML format defining the domain
----	------	--

### 7.15.3 Member Function Documentation

**void get ( const string & file )**

Read domain data from a data file.

Parameters

in	file	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

in	file	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

in	<i>geo_file</i>	Geo file
in	<i>bamg_file</i>	Bamg file
in	<i>mesh_file</i>	File where the generated mesh is saved

**Domain& operator\*= ( real\_t a )**

Operator \*=

Rescale domain coordinates by multiplying by a factor

Parameters

in	<i>a</i>	Value to multiply by
----	----------	----------------------

**void insertVertex ( real\_t x, real\_t y, real\_t h, int code )**

Insert a vertex.

Parameters

in	<i>x</i>	x-coordinate of vertex
in	<i>y</i>	y-coordinate of vertex
in	<i>h</i>	mesh size around vertex
in	<i>code</i>	code of coordinate

**void insertVertex ( real\_t x, real\_t y, real\_t z, real\_t h, int code )**

Insert a vertex (3-D case)

Parameters

in	<i>x</i>	x-coordinate of vertex
in	<i>y</i>	y-coordinate of vertex
in	<i>z</i>	z-coordinate of vertex
in	<i>h</i>	mesh size around vertex
in	<i>code</i>	code of coordinate

**void insertLine ( size\_t n1, size\_t n2, int c )**

Insert a straight line.

Parameters

in	<i>n1</i>	Label of the first vertex of line
in	<i>n2</i>	Label of the second vertex of line

Parameters

in	<i>c</i>	Code to associate to created nodes (Dirichlet) or sides (Neumann) if < 0
----	----------	--

**void insertLine ( size\_t *n1*, size\_t *n2*, int *dc*, int *nc* )**

Insert a straight line.

Parameters

in	<i>n1</i>	Label of the first vertex of line
in	<i>n2</i>	Label of the second vertex of line
in	<i>dc</i>	Code to associate to created nodes (Dirichlet)
in	<i>nc</i>	Code to associate to created sides (Neumann)

**void insertCircle ( size\_t *n1*, size\_t *n2*, size\_t *n3*, int *c* )**

Insert a circular arc.

Parameters

in	<i>n1</i>	Label of vertex defining the first end of the arc
in	<i>n2</i>	Label of vertex defining the second end of the arc
in	<i>n3</i>	Label of vertex defining the center of the arc
in	<i>c</i>	Code to associate to created nodes (Dirichlet) or sides (Neumann) if < 0

**void insertCircle ( size\_t *n1*, size\_t *n2*, size\_t *n3*, int *dc*, int *nc* )**

Insert a circular arc.

Parameters

in	<i>n1</i>	Label of vertex defining the first end of the arc
in	<i>n2</i>	Label of vertex defining the second end of the arc
in	<i>n3</i>	Label of vertex defining the center of the arc
in	<i>dc</i>	Code to associate to created nodes (Dirichlet)
in	<i>nc</i>	Code to associate to created sides (Neumann)

**void insertRequiredVertex ( size\_t *v* )**

Insert a required (imposed) vertex.

Parameters

in	<i>v</i>	Label of vertex
----	----------	-----------------

**void insertRequiredEdge ( size\_t *e* )**

Insert a required (imposed) edge (or line)

Parameters

in	<i>e</i>	Label of line
----	----------	---------------

**void insertSubDomain ( size\_t *n*, int *code* )**

Insert subdomain.

Parameters

in	<i>n</i>	
in	<i>code</i>	

**void insertSubDomain ( size\_t *ln*, int *orient*, int *code* )**

Insert subdomain.

Parameters

in	<i>ln</i>	Line label
in	<i>orient</i>	Orientation (1 or -1)
in	<i>code</i>	Subdomain code or reference

**void setOutputFile ( string *file* )**

Define output mesh file.

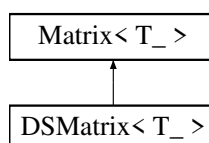
Parameters

in	<i>file</i>	String defining output mesh file
----	-------------	----------------------------------

## 7.16 DSMatrix< T\_ > Class Template Reference

To handle symmetric dense matrices.

Inheritance diagram for DSMatrix&lt; T\_ &gt;:



## 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](#) ([Mesh](#) &mesh, size\_t dof=0, int is\_diagonal=false)  
*Constructor using mesh to initialize matrix.*
- [~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 [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 [setRow](#) (size\_t i, const [Vect](#)< T\_ > &v)  
*Copy a given vector to a prescribed row in the matrix.*
- void [setColumn](#) (size\_t j, const [Vect](#)< T\_ > &v)  
*Copy a given vector to a prescribed column in 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.*
- [DSMatrix](#) & [operator+=](#) (const T\_ &x)  
*Operator +=.*
- [DSMatrix](#) & [operator-=](#) (const T\_ &x)

- Operator `--`.
- `int setLDLt ()`  
Factorize matrix ( $LDL^T$ )
- `void MultAdd (const Vect< T_ > &x, Vect< T_ > &y) const`  
Multiply matrix by vector  $\alpha * x$  and add result to  $y$ .
- `void MultAdd (T_ a, const Vect< T_ > &x, Vect< T_ > &y) const`  
Multiply matrix by vector  $\alpha * x$  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 DMatrix< 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.
- `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.
- `virtual void reset ()`  
Set matrix to 0 and reset factorization parameter.
- `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).
- `virtual void clear ()`  
brief Set all matrix entries to zero
- `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 \*=.*

### 7.16.1 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

$T_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
$_{\leftrightarrow}$	

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### 7.16.2 Constructor & Destructor Documentation

**DSMatrix ( size\_t *dim* )**

Constructor that for a symmetric matrix with given number of rows.

Parameters

in	<i>dim</i>	Number of rows
----	------------	----------------

**DSMatrix ( const DSMATRIX< T\_ > & *m* )**

Copy Constructor.

Parameters

in	<i>m</i>	<a href="#">DSMatrix</a> instance to copy
----	----------	---

**DSMatrix ( Mesh & *mesh*, size\_t *dof* = 0, int *is\_diagonal* = false )**

Constructor using mesh to initialize 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. 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.



Parameters

in	<i>is_diagonal</i>	Boolean argument to say is the matrix is actually a diagonal matrix or not.
----	--------------------	---

### 7.16.3 Member Function Documentation

**void setSize ( size\_t dim )**

Set size (number of rows) of matrix.

Parameters

in	<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

in	<i>i</i>	row index
in	<i>j</i>	column index
in	<i>val</i>	value to assign to a(i, j)

Implements [Matrix< T\\_ >](#).

**void getColumn ( size\_t j, Vect< T\_ > & v ) const**

Get j-th column vector.

Parameters

in	<i>j</i>	Index of column to extract
out	<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

in	<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

in	<i>i</i>	Index of row to extract
out	<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 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 j, 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 setDiag ( const T\_ & a )**

Set matrix as diagonal and assign its diagonal entries as a constant.

Parameters

in	<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

in	<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

in	<i>i</i>	row index
in	<i>j</i>	column index
in	<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>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	$i$	Row index
in	$j$	Column index

Warning

To modify a value of an entry of the matrix it is safer not to modify both lower and upper triangles. Otherwise, wrong values will be assigned. If not sure, use the member functions `set` or `add`.

Implements [Matrix< T\\_ >](#).

**DSMatrix& operator+= ( const T\_ & x )**

Operator +=.

Add constant value  $x$  to all matrix entries.

**DSMatrix& operator-= ( const T\_ & x )**

Operator -=.

Subtract constant value  $x$  from to all matrix entries.

**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	<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\\_ >](#).

**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	<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* )** [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	<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.

Implements [Matrix< T\\_ >](#).

**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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 [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 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.

## Parameters

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]

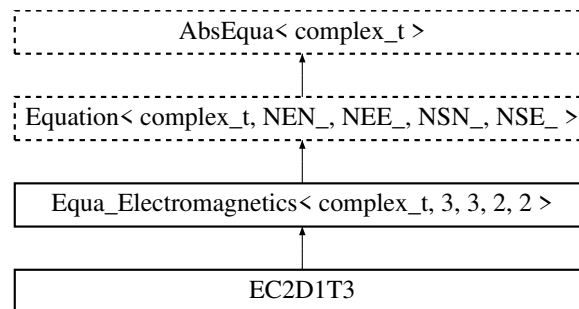
Operator \*.

Premultiply matrix entries by constant value x

## 7.17 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< complex_t > &bc)`

*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< complex_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< complex_t > &b)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< complex_t > &b, LocalVect< complex_t, NEE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< complex_t > &b, LocalVect< complex_t, NEN_ > &be, int dof)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< complex_t > &b, LocalVect< complex_t, NEN_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< complex_t > &b, LocalVect< complex_t, NSE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< complex_t > &b, int dof_type=NODE_FIELD, int flag=0)`

*Localize Element Vector.*
- `void SideVector (const Vect< complex_t > &b)`

*Localize Side Vector.*
- `void ElementNodeCoordinates ()`

*Localize coordinates of element nodes.*
- `void SideNodeCoordinates ()`

*Localize coordinates of side nodes.*
- `void ElementAssembly (Matrix< complex_t > *A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (PETScMatrix< complex_t > &A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (PETScVect< complex_t > &b)`

- Assemble element right-hand side vector into global one.*
  - void `ElementAssembly` (`BMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one.*
  - void `ElementAssembly` (`SkSMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one.*
  - void `ElementAssembly` (`SkMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one.*
  - void `ElementAssembly` (`SpMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one.*
  - void `ElementAssembly` (`TrMatrix`< `complex.t` > &`A`)
- Assemble element vector into global one.*
  - void `ElementAssembly` (`Vect`< `complex.t` > &`v`)
- Assemble side matrix into global one.*
  - void `SideAssembly` (`PETScMatrix`< `complex.t` > &`A`)
- Assemble side right-hand side vector into global one.*
  - void `SideAssembly` (`PETScVect`< `complex.t` > &`b`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`Matrix`< `complex.t` > \*`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SkSMatrix`< `complex.t` > &`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SkMatrix`< `complex.t` > &`A`)
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly` (`SpMatrix`< `complex.t` > &`A`)
- Assemble side (edge or face) vector into global one.*
  - void `SideAssembly` (`Vect`< `complex.t` > &`v`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`Matrix`< `complex.t` > \*`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SkSMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SkMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`SpMatrix`< `complex.t` > &`A`)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly` (`TrMatrix`< `complex.t` > &`A`)
- Assemble product of element matrix by element vector into global vector.*
  - void `AxbAssembly` (const `Element` &`el`, const `Vect`< `complex.t` > &`x`, `Vect`< `complex.t` > &`b`)
- Assemble product of side matrix by side vector into global vector.*
  - void `AxbAssembly` (const `Side` &`sd`, const `Vect`< `complex.t` > &`x`, `Vect`< `complex.t` > &`b`)
- Return number of element nodes.*
  - `size_t` `getNbNodes` () const
- Return number of element equations.*
  - `size_t` `getNbEq` () const
- void `setInitialSolution` (const `Vect`< `complex.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`< `complex_t` > & `getLinearSolver` ()  
*Return reference to linear solver instance.*
  - void `setSolver` (Iteration ls, Preconditioner pc=IDENT\_PREC)  
*Choose solver for the linear system.*
  - void `setMatrixType` (int t)  
*Choose type of matrix.*
  - int `solveLinearSystem` (Matrix< `complex_t` > \*A, Vect< `complex_t` > &b, Vect< `complex_t` > &x)  
*Solve the linear system with given matrix and right-hand side.*
  - int `solveLinearSystem` (Vect< `complex_t` > &b, Vect< `complex_t` > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.17.1 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).

Author

Rachid Touzani

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### 7.17.2 Constructor & Destructor Documentation

**EC2D1T3 ( const [Element](#) \* *el* )**

Constructor using element data.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
----	-----------	---

**EC2D1T3 ( const [Side](#) \* *side* )**

Constructor using side data.

Parameters

in	<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

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
in	<i>u</i>	Solution at previous iteration
in	<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

in	<i>sd</i>	Pointer to <a href="#">Side</a> instance
in	<i>u</i>	Solution at previous iteration
in	<i>time</i>	Time value [Default: 0]

### 7.17.3 Member Function Documentation

**void Magnetic ( real\_t *omega*, real\_t *coef* = 1. )**

Add magnetic contribution to matrix.

Parameters

in	<i>omega</i>	Angular frequency
in	<i>coef</i>	Coefficient to multiply by [Default: 1]

**void Electric ( real\_t *coef* = 1. )**

Add electric contribution to matrix.

Parameters

in	<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

in	<i>h</i>	<a href="#">Vect</a> instance containing magnetic field at element nodes
in	<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< complex\_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< complex\_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< complex\_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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--



**void ElementNodeVector ( const Vect< complex.t > & *b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.t, NSE\_ > & *be* )** [inherited]

Localize Element Vector from a Vect instance.

Parameters

in	<i>b</i>	Global vector to be localized.
----	----------	--------------------------------

## Parameters

out	<i>be</i>	Local vector, the length of which is
-----	-----------	--------------------------------------

**void ElementVector ( const Vect< complex.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< complex.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< complex.t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< complex.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< complex.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< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>in</i>	<i>A</i>	Global matrix stored as an SkMatrix instance
-----------	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>in</i>	<i>A</i>	Global matrix stored as an SpMatrix instance
-----------	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	A	Global matrix stored as an TrMatrix instance
----	---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< complex.t > &v )** [inherited]

Assemble element vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< complex.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< complex.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< complex.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< complex.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkSMatrix instance
----	---	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< complex.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< complex.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< complex.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< complex.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< complex.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< complex.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< complex\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< complex\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< complex\_t > & *x*, Vect< complex\_t > & *b* )** [inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< complex\_t > & *x*, Vect< complex\_t > & *b* )** [inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< complex\_t > \* *A*, Vect< complex\_t > & *b*, Vect< complex\_t > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< complex\_t > & *b*, Vect< complex\_t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.17.4 Member Data Documentation

**LocalVect<complex\_t,NEE\_> ePrev** [inherited]

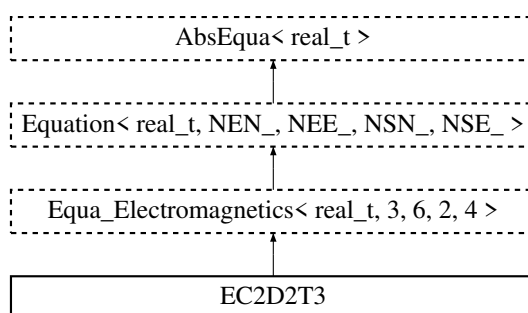
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.18 EC2D2T3 Class Reference

Eddy current problems in 2-D domains using transversal approximation.

Inheritance diagram for EC2D2T3:



## Public Member Functions

- **EC2D2T3** ()  
*Default Constructor.*
- **EC2D2T3** (const **Element** \*el)  
*Constructor using element data.*
- **EC2D2T3** (const **Side** \*sd)  
*Constructor using one side data.*
- **EC2D2T3** (const **Side** \*sd1, const **Side** \*sd2)  
*Constructor using two side data.*
- **~EC2D2T3** ()  
*Destructor.*
- void **RHS** (real\_t coef=1.)  
*Compute Contribution to Right-Hand Side.*
- void **FEBlock** (real\_t omega)  
*Compute Finite Element Diagonal Block.*
- void **BEBlocks** (size\_t n1, size\_t n2, SpMatrix< real\_t > &L, SpMatrix< real\_t > &U, SpMatrix< real\_t > &D)  
*Compute boundary element blocks.*
- complex\_t **Constant** (real\_t omega, const Vect< real\_t > &u, complex\_t &I)  
*Compute constant to multiply by potential.*
- real\_t **MagneticPressure** (const Vect< real\_t > &u)  
*Compute magnetic pressure in element.*
- void **updateBC** (const **Element** &el, const Vect< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const Vect< real\_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< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be)

- Localize Element Vector from a Vect instance.*

  - void **ElementSideVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, NSE\_ > &be)

*Localize Element Vector from a Vect instance.*

  - void **ElementVector** (const **Vect**< **real.t** > &b, int dof.type=NODE.FIELD, int flag=0)

*Localize Element Vector.*

  - void **SideVector** (const **Vect**< **real.t** > &b)

*Localize Side Vector.*

  - void **ElementNodeCoordinates** ()

*Localize coordinates of element nodes.*

  - void **SideNodeCoordinates** ()

*Localize coordinates of side nodes.*

  - void **ElementAssembly** (**Matrix**< **real.t** > \*A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**PETScMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**PETScVect**< **real.t** > &b)

*Assemble element right-hand side vector into global one.*

  - void **ElementAssembly** (**BMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SkSMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SkMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**SpMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**TrMatrix**< **real.t** > &A)

*Assemble element matrix into global one.*

  - void **ElementAssembly** (**Vect**< **real.t** > &v)

*Assemble element vector into global one.*

  - void **SideAssembly** (**PETScMatrix**< **real.t** > &A)

*Assemble side matrix into global one.*

  - void **SideAssembly** (**PETScVect**< **real.t** > &b)

*Assemble side right-hand side vector into global one.*

  - void **SideAssembly** (**Matrix**< **real.t** > \*A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SkSMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SkMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**SpMatrix**< **real.t** > &A)

*Assemble side (edge or face) matrix into global one.*

  - void **SideAssembly** (**Vect**< **real.t** > &v)

*Assemble side (edge or face) vector into global one.*

  - void **DGElementAssembly** (**Matrix**< **real.t** > \*A)

*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void **DGElementAssembly** (**SkSMatrix**< **real.t** > &A)

- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void **DGElementAssembly** (**SkMatrix**< **real\_t** > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void **DGElementAssembly** (**SpMatrix**< **real\_t** > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void **DGElementAssembly** (**TrMatrix**< **real\_t** > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void **AxbAssembly** (const **Element** &el, const **Vect**< **real\_t** > &x, **Vect**< **real\_t** > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void **AxbAssembly** (const **Side** &sd, const **Vect**< **real\_t** > &x, **Vect**< **real\_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**< **real\_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**< **real\_t** > & **getLinearSolver** ()
- Return reference to linear solver instance.*
  - void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)
- Choose solver for the linear system.*
  - void **setMatrixType** (int t)
- Choose type of matrix.*
  - int **solveLinearSystem** (**Matrix**< **real\_t** > \*A, **Vect**< **real\_t** > &b, **Vect**< **real\_t** > &x)
- Solve the linear system with given matrix and right-hand side.*
  - int **solveLinearSystem** (**Vect**< **real\_t** > &b, **Vect**< **real\_t** > &x)
- Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.18.1 Detailed Description

Eddy current problems in 2-D domains using transversal approximation.

Builds finite element arrays for time harmonic eddy current problems in 2-D domains with transversal configurations (Magnetic field has two nonzero components). Uses 3-Node triangles.

The unknown is the time-harmonic scalar potential (complex valued).

Author

Rachid Touzani

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### 7.18.2 Member Function Documentation

**void updateBC ( const [Element](#) &el, const [Vect](#)< [real\\_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](#)< [real\\_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>• <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>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< real.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 <code>Element</code> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > &*b*, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real.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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes SkSMatrix, SkMatrix, SpMatrix)
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real.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< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & *v* )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>



**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.18.3 Member Data Documentation

**LocalVect<real.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

## 7.19 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 ().*

### 7.19.1 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`.

Author

Rachid Touzani

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### 7.19.2 Constructor & Destructor Documentation

**Edge ( )**

Default Constructor.

Initializes data to zero

**Edge ( *size\_t label* )**

Constructor with label.

Define an edge by giving its `label`

### 7.19.3 Member Function Documentation

**void DOF ( *size\_t i*, *size\_t dof* )**

Define label of DOF.

Parameters

in	<i>i</i>	DOF index
in	<i>dof</i>	Its label

**void setDOF ( *size\_t &first\_dof*, *size\_t nb\_dof* )**

Define number of DOF.

Parameters

in,out	<i>first_dof</i>	Label of the first DOF in input that is actualized
in	<i>nb_dof</i>	Number of DOF

**void setCode ( *size\_t dof*, *int code* )**

Assign code `code` to DOF number `dof`.

Parameters

in	<i>dof</i>	index of dof for assignment.
----	------------	------------------------------

Parameters

in	code	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

in	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

## 7.20 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)*

### 7.20.1 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.

Author

Rachid Touzani

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### 7.20.2 Member Function Documentation

**`void selectCode ( int code, int dof = 1 )`**

Select edges having a given code for a given degree of freedom.

Parameters

in	<i>code</i>	Code that edges share
in	<i>dof</i>	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

in	<i>code</i>	Code of edges to exclude
in	<i>dof</i>	Degree of Freedom label [Default: 1]

## 7.21 EigenProblemSolver Class Reference

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.

## 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.*

### 7.21.1 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.

Author

Rachid Touzani

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### 7.21.2 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	$M$	"Mass" matrix
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

## Parameters

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	<i>lumped</i>	Mass matrix is lumped ( <i>true</i> ) or not ( <i>false</i> ) [Default: true]

### 7.21.3 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	<i>K</i>	Stiffness matrix instance
in	<i>M</i>	Mass matrix instance where diagonal terms are stored as a vector.

**void setMatrix ( DSMatrix< 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	<i>K</i>	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

in	<i>eq</i>	Reference to equation instance
in	<i>lumped</i>	Mass matrix is lumped ( <i>true</i> ) or not ( <i>false</i> ) [Default: <i>true</i> ]

**int run ( int nb = 0 )**

Run the eigenproblem solver.

Parameters

in	<i>nb</i>	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

in	<i>el</i>	Reference to <a href="#">Element</a> class
in	<i>eK</i>	Pointer to element stiffness (or assimilated) matrix

Parameters

in	<i>eM</i>	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

in	<i>sd</i>	Reference to <a href="#">Side</a> class
in	<i>sK</i>	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

in	<i>nb_eigv</i>	Number of eigenvalues to be extracted
in	<i>ss_dim</i>	Subspace dimension. Must be at least equal to the number eigenvalues to seek. [Default: <i>nb_eigv</i> ]

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.

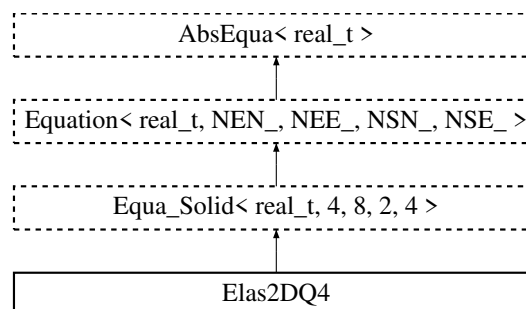
Parameters

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.

## 7.22 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**< real.t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< real.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**< real.t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< real.t > &b, **LocalVect**< real.t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< real.t > &b, **LocalVect**< real.t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< real.t > &b, **LocalVect**< real.t, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const **Vect**< real.t > &b, **LocalVect**< real.t, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const **Vect**< real.t > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const **Vect**< real.t > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< real.t > \*A)  
*Assemble element matrix into global one.*

- void [ElementAssembly](#) (PETScMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScVect< real.t > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) (BMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SpMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (TrMatrix< real.t > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (Vect< real.t > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) (PETScMatrix< real.t > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) (PETScVect< real.t > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) (Matrix< real.t > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SpMatrix< real.t > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (Vect< real.t > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) (Matrix< real.t > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkSMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SpMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (TrMatrix< real.t > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const Vect< real.t > &x, Vect< real.t > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const Vect< real.t > &x, Vect< real.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< real_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< real_t > & getLinearSolver ()`  
*Return reference to linear solver instance.*
- `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`  
*Choose solver for the linear system.*
- `void setMatrixType (int t)`  
*Choose type of matrix.*
- `int solveLinearSystem (Matrix< real_t > *A, Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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 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.

### 7.22.2 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]



### 7.22.3 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	<i>E</i>	Young's modulus
in	<i>nu</i>	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	<i>E</i>	Young's modulus
in	<i>nu</i>	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	<i>bf</i>	Vector containing source at element nodes (DOF by DOF).
in	<i>opt</i>	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	<i>sf</i>	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< real.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< real.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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------



## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

<i>in</i>	<i>A</i>	Global matrix stored as an SkSMatrix instance
-----------	----------	---

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	A	Global matrix stored as an SkMatrix instance
----	---	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	A	Global matrix stored as an SpMatrix instance
----	---	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

**Parameters**

in	v	Global vector (Vect instance)
----	---	-------------------------------

**Warning**

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.22.4 Member Data Documentation

**LocalVect<real.t,NEE-> ePrev** [inherited]

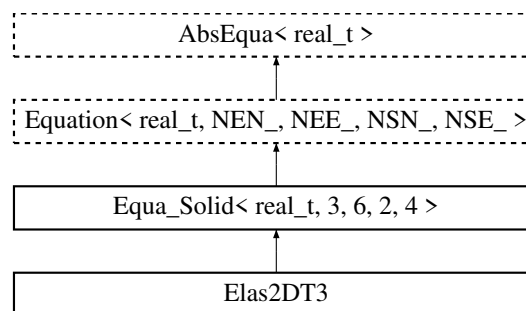
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.23 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**< **real.t** > &bc)
- Update Right-Hand side by taking into account essential boundary conditions.*

  - void **updateBC** (const **Vect**< **real.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**< **real.t** > &b)
- Localize Element Vector from a Vect instance.*

  - void **ElementNodeVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEE\_** > &be)
- Localize Element Vector from a Vect instance.*

  - void **ElementNodeVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEN\_** > &be, int dof)
- Localize Element Vector from a Vect instance.*

  - void **ElementNodeVectorSingleDOF** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEN\_** > &be)
- Localize Element Vector from a Vect instance.*

  - void **ElementSideVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NSE\_** > &be)
- Localize Element Vector from a Vect instance.*

  - void **ElementVector** (const **Vect**< **real.t** > &b, int dof\_type=NODE.FIELD, int flag=0)
- Localize Element Vector.*

  - void **SideVector** (const **Vect**< **real.t** > &b)
- Localize Side Vector.*

  - void **ElementNodeCoordinates** ()



- Localize coordinates of element nodes.*

  - void [SideNodeCoordinates](#) ()
- Localize coordinates of side nodes.*

  - void [ElementAssembly](#) (Matrix< real.t > \*A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (PETScMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (PETScVect< real.t > &b)
- Assemble element right-hand side vector into global one.*

  - void [ElementAssembly](#) (BMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (SkSMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) (Vect< real.t > &v)
- Assemble element vector into global one.*

  - void [SideAssembly](#) (PETScMatrix< real.t > &A)
- Assemble side matrix into global one.*

  - void [SideAssembly](#) (PETScVect< real.t > &b)
- Assemble side right-hand side vector into global one.*

  - void [SideAssembly](#) (Matrix< real.t > \*A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) (SkSMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) (SkMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) (SpMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) (Vect< real.t > &v)
- Assemble side (edge or face) vector into global one.*

  - void [DGElementAssembly](#) (Matrix< real.t > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) (SkSMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [AxbAssembly](#) (const [Element](#) &el, const Vect< real.t > &x, Vect< real.t > &b)

*Assemble product of element matrix by element vector into global vector.*

- void **AxbAssembly** (const **Side** &sd, const **Vect**< **real\_t** > &x, **Vect**< **real\_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**< **real\_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**< **real\_t** > & **getLinearSolver** ()

*Return reference to linear solver instance.*

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

*Choose solver for the linear system.*

- void **setMatrixType** (int t)

*Choose type of matrix.*

- int **solveLinearSystem** (**Matrix**< **real\_t** > \*A, **Vect**< **real\_t** > &b, **Vect**< **real\_t** > &x)

*Solve the linear system with given matrix and right-hand side.*

- int **solveLinearSystem** (**Vect**< **real\_t** > &b, **Vect**< **real\_t** > &x)

*Solve the linear system with given right-hand side.*

## Public Attributes

- **LocalMatrix**< **real\_t**, NEE\_, NEE\_ > **eMat**

*LocalMatrix instance containing local matrix associated to current element.*

- **LocalMatrix**< **real\_t**, NSE\_, NSE\_ > **sMat**

*LocalMatrix instance containing local matrix associated to current side.*

- **LocalVect**< **real\_t**, NEE\_ > **ePrev**

*LocalVect instance containing local vector associated to current element.*

- **LocalVect**< **real\_t**, NEE\_ > **eRHS**

*LocalVect instance containing local right-hand side vector associated to current element.*

- **LocalVect**< **real\_t**, NEE\_ > **eRes**

*LocalVect instance containing local residual vector associated to current element.*

- **LocalVect**< **real\_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 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.

### 7.23.2 Constructor & Destructor Documentation

**Elas2DT3 ( )**

Default Constructor.

Constructs an empty equation.

**Elas2DT3 ( Mesh & ms )**

Constructor using **Mesh** data.

Parameters

<b>in</b>	<i>ms</i>	<b>Mesh</b> instance
-----------	-----------	----------------------

**Elas2DT3 ( const **Element** \* el )**

Constructor using element data.

Parameters

<i>el</i>	Pointer to <a href="#">Element</a> instance
-----------	---

**Elas2DT3 ( const Side \* *sd* )**

Constructor using side data.

Parameters

<i>sd</i>	Pointer to <a href="#">Side</a> 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

### 7.23.3 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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<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

in	<i>f</i>	Vector containing source at element nodes (DOF by DOF)
in	<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

in	<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

in	<i>f</i>	Vect 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

in	<i>ud</i>	UserData 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 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

in	<i>f</i>	Vect instance that contains contact data
in	<i>coef</i>	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

in	<i>r</i>	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

in	$f$	
in	$penal$	Penalty parameter that was used to impose contact condition
out	$p$	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

in	$s$	vector of principal stresses
in	$vm$	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

in	$coef$	Value of penalty parameter [Default: 1.e20]
----	--------	---

**void updateBC ( const Element &el, const Vect< real.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< real.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>• <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>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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_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< real.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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes SkSMatrix, SkMatrix, SpMatrix)
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real.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< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > &v )** [inherited]

Assemble side (edge or face) vector into global one.



## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.23.4 Member Data Documentation

**LocalVect<real.t,NEE\_> ePrev** [inherited]

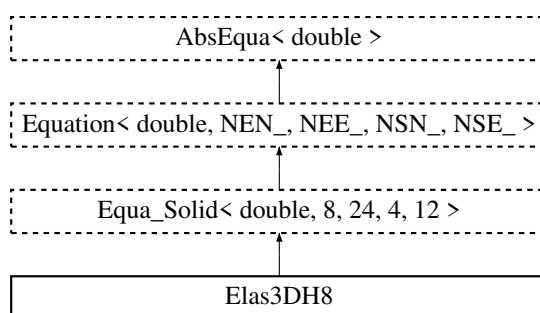
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.24 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](#)< double > &bc)
- Update Right-Hand side by taking into account essential boundary conditions.*

  - void [updateBC](#) (const [Vect](#)< double > &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](#)< double > &b)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< double > &b, [LocalVect](#)< double, NEE\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< double > &b, [LocalVect](#)< double, NEN\_ > &be, int dof)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< double > &b, [LocalVect](#)< double, NE↔N\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementSideVector](#) (const [Vect](#)< double > &b, [LocalVect](#)< double, NSE\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementVector](#) (const [Vect](#)< double > &b, int dof\_type=NODE\_FIELD, int flag=0)
- Localize Element Vector.*

  - void [SideVector](#) (const [Vect](#)< double > &b)
- Localize Side Vector.*

  - void [ElementNodeCoordinates](#) ()
- Localize coordinates of element nodes.*

  - void [SideNodeCoordinates](#) ()
- Localize coordinates of side nodes.*

  - void [ElementAssembly](#) ([Matrix](#)< double > \*A)
- Assemble element matrix into global one.*

- void [ElementAssembly](#) (PETScMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (PETScVect< double > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) (BMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkSMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SkMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (SpMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (TrMatrix< double > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) (Vect< double > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) (PETScMatrix< double > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) (PETScVect< double > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) (Matrix< double > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkSMatrix< double > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SkMatrix< double > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (SpMatrix< double > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) (Vect< double > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) (Matrix< double > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkSMatrix< double > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SkMatrix< double > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (SpMatrix< double > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) (TrMatrix< double > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const Vect< double > &x, Vect< double > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const Vect< double > &x, Vect< double > &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< double > &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< double > & getLinearSolver ()`  
*Return reference to linear solver instance.*
- `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`  
*Choose solver for the linear system.*
- `void setMatrixType (int t)`  
*Choose type of matrix.*
- `int solveLinearSystem (Matrix< double > *A, Vect< double > &b, Vect< double > &x)`  
*Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< double > &b, Vect< double > &x)`  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< double, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< double, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< double, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< double, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< double, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< double, 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.*

### 7.24.1 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.

### 7.24.2 Constructor & Destructor Documentation

**Elas3DH8** ( )

Default Constructor.

Constructs an empty equation.

### 7.24.3 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

in	<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

in	<i>bf</i>	Vector containing source at element nodes (DOF by DOF).
in	<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

in	coef	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	coef	coefficient to multiply by the vector before adding [Default: 1]
----	------	--

**void updateBC ( const Element & el, const Vect< double > & 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< double > & 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< double > & 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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< double > & b, LocalVect< double , 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< double > & b, LocalVect< double , 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< double > & b, LocalVect< double , 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< double > & b, LocalVect< double , 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< double > & 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< double > & 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< double > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< double > & 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< double > & 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< double > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< double > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< double > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< double > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< double > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< double > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< double > & A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< double > & b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< double > \* 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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< double > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---



**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< double > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< double > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< double > & v )** [inherited]

Assemble side (edge or face) vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

**Warning**

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< double > \* 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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< double > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< double > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< double > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< double > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< double > & *x*, Vect< double > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< double > & *x*, Vect< double > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< double > \* *A*, Vect< double > & *b*, Vect< double > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< double > & b, Vect< double > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.24.4 Member Data Documentation

**LocalVect<double ,NEE\_> ePrev** [inherited]

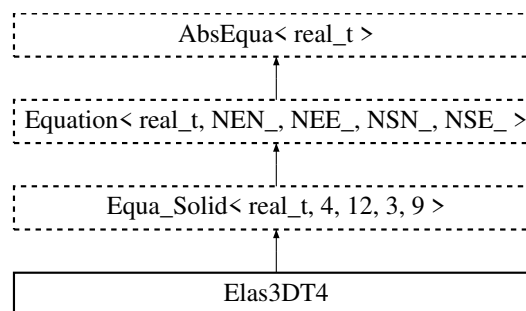
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.25 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**< **real.t** > &bc)
- Update Right-Hand side by taking into account essential boundary conditions.*

  - void **updateBC** (const **Vect**< **real.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< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const Vect< real\_t > &b, LocalVect< real\_t, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const Vect< real\_t > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const Vect< real\_t > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (Matrix< real\_t > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (PETScMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (PETScVect< real\_t > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (BMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SkSMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SkMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (SpMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (TrMatrix< real\_t > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (Vect< real\_t > &v)  
*Assemble element vector into global one.*
- void **SideAssembly** (PETScMatrix< real\_t > &A)  
*Assemble side matrix into global one.*
- void **SideAssembly** (PETScVect< real\_t > &b)  
*Assemble side right-hand side vector into global one.*
- void **SideAssembly** (Matrix< real\_t > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void **SideAssembly** (SkSMatrix< real\_t > &A)  
*Assemble side (edge or face) matrix into global one.*

- void `SideAssembly` (`SkMatrix`< `real.t` > &`A`)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SpMatrix`< `real.t` > &`A`)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`Vect`< `real.t` > &`v`)  
*Assemble side (edge or face) vector into global one.*
- void `DGElementAssembly` (`Matrix`< `real.t` > \*`A`)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkSMatrix`< `real.t` > &`A`)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkMatrix`< `real.t` > &`A`)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SpMatrix`< `real.t` > &`A`)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`TrMatrix`< `real.t` > &`A`)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `AxbAssembly` (const `Element` &`el`, const `Vect`< `real.t` > &`x`, `Vect`< `real.t` > &`b`)  
*Assemble product of element matrix by element vector into global vector.*
- void `AxbAssembly` (const `Side` &`sd`, const `Vect`< `real.t` > &`x`, `Vect`< `real.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`< `real.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`< `real.t` > & `getLinearSolver` ()  
*Return reference to linear solver instance.*
- void `setSolver` (`Iteration` `ls`, `Preconditioner` `pc`=`IDENT_PREC`)  
*Choose solver for the linear system.*
- void `setMatrixType` (int `t`)  
*Choose type of matrix.*
- int `solveLinearSystem` (`Matrix`< `real.t` > \*`A`, `Vect`< `real.t` > &`b`, `Vect`< `real.t` > &`x`)  
*Solve the linear system with given matrix and right-hand side.*
- int `solveLinearSystem` (`Vect`< `real.t` > &`b`, `Vect`< `real.t` > &`x`)  
*Solve the linear system with given right-hand side.*



## Public Attributes

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

### 7.25.1 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.

### 7.25.2 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	$f$	<a href="#">Vect</a> 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

in	$f$	<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

in	$K$	Stiffness matrix
in	$M$	Vector containing diagonal mass matrix

**virtual void MassToLHS ( real\_t coef = 1 )** [virtual], [inherited]

Add consistent mass contribution to left-hand side.

Parameters

in	$coef$	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< real.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< real.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< real.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 Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & *b*, LocalVect< real\_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< real\_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< real\_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< real.t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real.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< real\_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< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real\_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< real\_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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkSMatrix instance
----	-----	---

Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & el, const Vect< real\_t > & x, Vect< real\_t > & b )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

## Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

## Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

### 7.25.3 Member Data Documentation

**LocalVect<real\_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

## 7.26 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.



### 7.26.1 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

#### Author

Rachid Touzani

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### 7.26.2 Constructor & Destructor Documentation

**Element ( `size_t label`, `const string & shape` )**

Constructor initializing label, shape of element.

#### Parameters

in	<i>label</i>	Label to assign to element.
in	<i>shape</i>	Shape of element (See class description).

**Element ( `size_t label`, `int shape` )**

Constructor initializing label, shape of element.

#### Parameters

in	<i>label</i>	Label to assign to element.
in	<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

in	<i>label</i>	Label to assign to element.
in	<i>shape</i>	Shape of element (See class description).

Parameters

in	<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

in	<i>label</i>	Label to assign to element.
in	<i>shape</i>	Shape of element (See enum ElementShape in <a href="#">Mesh</a> ).
in	<i>c</i>	Code to assign to element (useful for media properties).

### 7.26.3 Member Function Documentation

**void setLabel ( size\_t *i* )**

Define label of element.

Parameters

in	<i>i</i>	Label to assign to element
----	----------	----------------------------

**void setCode ( int *c* )**

Define code of element.

Parameters

in	<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.
----	-----------	---

Parameters

in	<i>k</i>	Local label.
----	----------	--------------

**void Add ( Element \* *el* )**

Add a neighbor element.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
----	-----------	---

**void set ( Element \* *el*, int *n* )**

Add a neighbor element and set its label.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
in	<i>n</i>	Neighbor element number to assign

**void setDOF ( size\_t *i*, size\_t *dof* )**

Define label of DOF.

Parameters

in	<i>i</i>	Index of DOF.
in	<i>dof</i>	Label of DOF to assign.

**void setCode ( size\_t *dof*, int *code* )**

Assign code to a DOF.

Parameters

in	<i>dof</i>	Index of dof for assignment.
in	<i>code</i>	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

in	<i>nd</i>	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

in	<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

in	<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

in	<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

in	<i>i</i>	Index of element to look for.
----	----------	-------------------------------

Note

This method returns valid information only if the [Mesh](#) member function [Mesh::getElement↵NeighborElements\(\)](#) 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::getElement↵NeighborElements\(\)](#) 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 hexahedra 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 ( <i>nd</i> [0] , <i>nd</i> [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

## 7.27 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)*

### 7.27.1 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.

Author

Rachid Touzani

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### 7.27.2 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

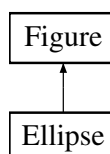
<b>in</b>	<i>level</i>	Level of elements to select
-----------	--------------	-----------------------------

Elements having a given level (for mesh adaption) are selected in a list

## 7.28 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 ellipse 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.*

### 7.28.1 Detailed Description

To store and treat an ellipsoidal figure.

### 7.28.2 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 ellipse 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]

### 7.28.3 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

Parameters

in	<i>a</i>	Vector defining the translation
----	----------	---------------------------------

**Ellipse& operator+= ( real.t a )**

Operator \*=

Scale ellipse by a factor a

Parameters

in	<i>a</i>	Scaling value
----	----------	---------------

**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

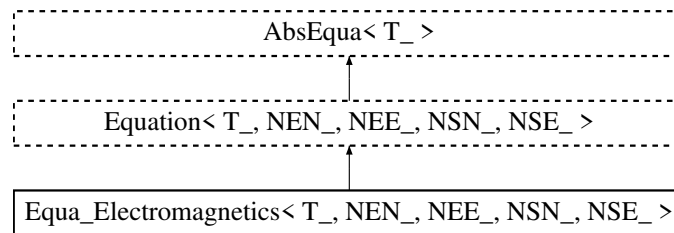
Returns

Signed distance

## 7.29 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.*
- void [setMatrixType](#) (int t)  
*Choose type of matrix.*
- int [solveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int [solveLinearSystem](#) ([Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Solve the linear system with given right-hand side.*

## 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.*

### 7.29.1 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

Author

Rachid Touzani

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### 7.29.2 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

#### 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>• <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>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

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<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<sub>-</sub> > & b, int dof\_type = NODE\_FIELD, int flag = 0 )**  
 [inherited]

Localize [Element](#) Vector.

#### Parameters

in	<i>b</i>	Global vector to be localized
----	----------	-------------------------------



#### 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>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

<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 ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

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 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

<i>A</i>	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

<i>b</i>	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	<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

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

#### 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>



**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.29.3 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

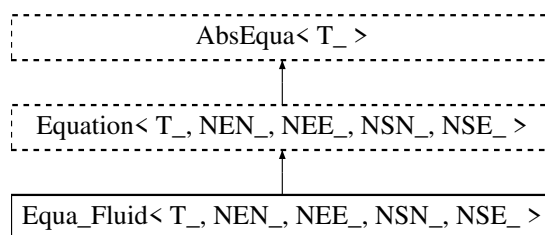
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.30 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** (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.*
- `void setMatrixType (int t)`  
*Choose type of matrix.*
- `int solveLinearSystem (Matrix< T_ > *A, Vect< T_ > &b, Vect< T_ > &x)`  
*Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< T_ > &b, Vect< T_ > &x)`  
*Solve the linear system with given right-hand side.*

## 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.*

### 7.30.1 Detailed Description

```
template<class T_ = real_t, size_t NEN_ = 3, size_t NEE_ = 3, size_t NSN_ = 2, size_t NSE_ = 2>
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

Author

Rachid Touzani

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### 7.30.2 Constructor & Destructor Documentation

**Equa\_Fluid ( )**

Default constructor.

Constructs an empty equation.

### 7.30.3 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>• <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>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

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
----	----------	-------------------------------

## 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>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

<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 ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

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 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="#">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	<i>A</i>	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	<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	$v$	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

## 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

## 7.30.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

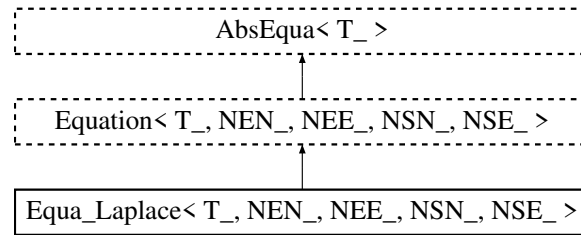
This vector has been stored as the one at previous iteration or previous time step

## 7.31 Equa\_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 [LHS](#) (real.t coef=1.)  
*Add finite element matrix to left-hand side.*
- virtual void [BodyRHS](#) (const [Vect](#)< real.t > &f)  
*Add body source term to right-hand side.*
- virtual void [BoundaryRHS](#) (const [Vect](#)< real.t > &h)  
*Add boundary source term to right-hand side.*
- int [run](#) ()  
*Build and solve the linear system of equations using an iterative method.*
- void [build](#) ()  
*Build global matrix and right-hand side.*
- 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.*
- 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.*
- void **setMatrixType** (int t)  
*Choose type of matrix.*
- int **solveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (**Vect**< T\_ > &b, **Vect**< T\_ > &x)  
*Solve the linear system with given right-hand side.*

## 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.*

### 7.3.1.1 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 Parameters

$T\_$	Data type (real_t, float, complex<real_t>, ...)
$NE_{\leftrightarrow} N\_$	Number of element nodes
$NE_{\leftrightarrow} E\_$	Number of element equations
$NS_{\leftrightarrow} N\_$	Number of side nodes
$NS_{\leftrightarrow} E\_$	Number of side equations

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### 7.3.1.2 Constructor & Destructor Documentation

**Equa\_Laplace ( )**

Default constructor.

Constructs an empty equation.

### 7.3.1.3 Member Function Documentation

**virtual void LHS ( real\_t *coef* = 1. )** [virtual]

Add finite element matrix to left-hand side.

Parameters

in	<i>coef</i>	Value to multiply by the added matrix
----	-------------	---------------------------------------

Reimplemented in [Laplace2DT3](#), [Laplace2DFVT](#), and [Laplace1DL2](#).

**virtual void BodyRHS ( const Vect< real\_t > &*f* )** [virtual]

Add body source term to right-hand side.

Parameters

in	<i>f</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#), [Laplace1DL2](#), and [Laplace1DL3](#).

**virtual void BoundaryRHS ( const Vect< real.t > & h )** [virtual]

Add boundary source term to right-hand side.

Parameters

in	<i>h</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#), [Laplace1DL2](#), and [Laplace1DL3](#).

**int run ( )**

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (`eps=-1`) or the GMRES method if not. The solution is stored in the vector `u` given in the constructor.

Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is 1.e-8

**void build ( )**

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.

**void build ( EigenProblemSolver & e )**

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>• <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>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

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	$b$	Global vector to be localized.
out	$be$	Local vector, the length of which is the total number of element equations.
in	$dof$	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	$b$	Global vector to be localized.
out	$be$	Local vector, the length of which is the total number of element equations.

## Remarks

Vector  $\mathbf{b}$  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	$b$	Global vector to be localized.
out	$be$	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	$b$	Global vector to be localized
----	-----	-------------------------------

#### 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>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

<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 ElementAssembly ( SpMatrix< T\_ > & A )** [inherited]

Assemble element matrix into global one.

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 ElementAssembly ( TrMatrix< 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 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

## 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>

**void setMatrixType ( int  $t$  )** [inherited]

Choose type of matrix.

Parameters

in	$t$	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	-----	---

**int solveLinearSystem ( Matrix< T\_ > \*  $A$ , Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$  )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	$A$	Pointer to matrix of the system
in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

**int solveLinearSystem ( Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$  )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	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.

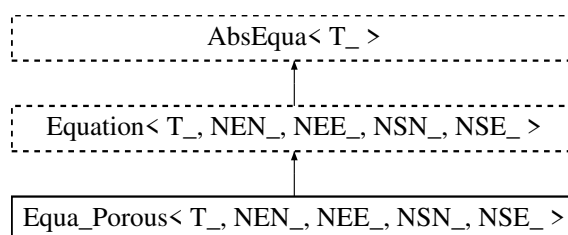
This vector has been stored as the one at previous iteration or previous time step

### 7.32 Equa\_Porous< T\_, NEN\_, NEE\_, NSN\_, NSE\_ > Class Template Reference

Abstract class for Porous Media Finite Element classes.

Inheritance diagram for Equa\_Porous< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >:





## Public Member Functions

- [Equa\\_Porous](#) ()  
*Default constructor.*
- virtual [~Equa\\_Porous](#) ()  
*Destructor.*
- virtual void [Mobility](#) ()  
*Add mobility term to the 0-th order element matrix.*
- virtual void [Mass](#) ()  
*Add porosity term to the 1-st order element matrix.*
- virtual void [BodyRHS](#) (const [Vect](#)< [real\\_t](#) > &bf, int opt=[GLOBAL\\_ARRAY](#))  
*Add source 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 [run](#) ()  
*Run the equation.*
- void [Mu](#) (const string &exp)  
*Set viscosity 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.*
  - void **setMatrixType** (int t)
- Choose type of matrix.*
  - int **solveLinearSystem** (**Matrix**< T\_ > \*A, **Vect**< T\_ > &b, **Vect**< T\_ > &x)
- Solve the linear system with given matrix and right-hand side.*
  - int **solveLinearSystem** (**Vect**< T\_ > &b, **Vect**< T\_ > &x)
- Solve the linear system with given right-hand side.*

## 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.*

### 7.32.1 Detailed Description

**template<class T\_, size\_t NEN\_, size\_t NEE\_, size\_t NSN\_, size\_t NSE\_>**  
**class OFELI::Equa\_Porous< T\_, NEN\_, NEE\_, NSN\_, NSE\_ >**

Abstract class for Porous Media Finite Element classes.

Template Parameters

<T_>	data type (real_t, float, ...)
<NEN>	Number of element nodes
<NEE_<_>	Number of element equations
<NSN_<_>	Number of side nodes
<NSE_>	Number of side equations

### 7.32.2 Constructor & Destructor Documentation

**Equa\_Porous ( )**

Default constructor.  
 Constructs an empty equation.

### 7.32.3 Member Function Documentation

**virtual void BodyRHS ( const Vect< real\_t > &bf, int opt = GLOBAL\_ARRAY )** [virtual]

Add source 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 in [WaterPorous2D](#).

**virtual void BoundaryRHS ( const Vect< real\_t > &sf, int opt = GLOBAL\_ARRAY )**  
 [virtual]

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

### 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 in [WaterPorous2D](#).

```
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. If transient analysis is chosen, 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 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>• <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>• <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	<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

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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.32.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

[LocalVect](#) instance containing local vector associated to current element.

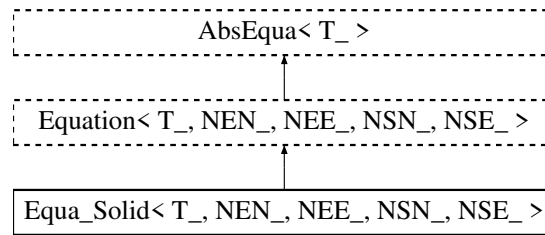
This vector has been stored as the one at previous iteration or previous time step

## 7.33 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.*

- void **setMatrixType** (int t)  
*Choose type of matrix.*
- int **solveLinearSystem** (Matrix< T\_ > \*A, Vect< T\_ > &b, Vect< T\_ > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (Vect< T\_ > &b, Vect< T\_ > &x)  
*Solve the linear system with given right-hand side.*

## 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.*

### 7.33.1 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

<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

## 7.33.2 Constructor &amp; Destructor Documentation

**Equa\_Solid ( )**

Default constructor.

Constructs an empty equation.

## 7.33.3 Member Function Documentation

**virtual void LMassToLHS ( real\_t coef = 1 )** [virtual]

Add lumped mass contribution to left-hand side.

Parameters

in	<i>coef</i>	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

in	<i>coef</i>	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

in	<i>coef</i>	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

in	<i>coef</i>	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>• <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 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>• 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

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	<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

<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

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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given right-hand side.



Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

### 7.33.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

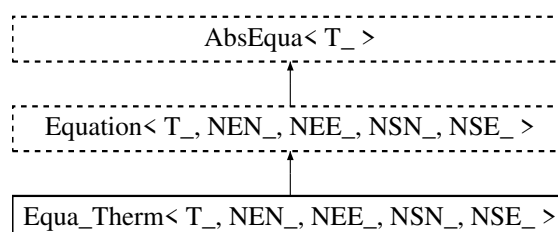
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.34 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.*
- void `setMatrixType` (int `t`)  
*Choose type of matrix.*
- int `solveLinearSystem` (`Matrix`< `T_` > \*`A`, `Vect`< `T_` > &`b`, `Vect`< `T_` > &`x`)  
*Solve the linear system with given matrix and right-hand side.*
- int `solveLinearSystem` (`Vect`< `T_` > &`b`, `Vect`< `T_` > &`x`)  
*Solve the linear system with given right-hand side.*

## 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.*

### 7.34.1 Detailed Description

```
template<class T_, size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>
class OFELI::Equa_Therm< T_, NEN_, NEE_, NSN_, NSE_ >
```

Abstract class for Heat transfer Finite Element classes.

Template Parameters

<T_>	data type (real_t, float, ...)
<NEN>	Number of element nodes
<NEE_>	Number of element equations
<NSN_>	Number of side nodes
<NSE_>	Number of side equations

### 7.34.2 Constructor & Destructor Documentation

**Equa\_Therm ( )**

Default constructor.  
Constructs an empty equation.

### 7.34.3 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	<i>coef</i>	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

in	<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

in	<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

in	<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

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 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

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 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	<i>s</i>	Reference to used <a href="#">TimeStepping</a> instance
----	----------	---

**void build ( EigenProblemSolver & e )**

Build the linear system for an eigenvalue problem.

Parameters

in	<i>e</i>	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>• <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 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 dof 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

<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	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

<i>A</i>	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

<i>b</i>	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="#">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

<i>in</i>	<i>A</i>	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

<code>A</code>	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

<code>in</code>	<code>A</code>	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

<code>in</code>	<code>A</code>	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

<code>in</code>	<code>A</code>	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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< T\_ > \* *A*, Vect< T\_ > & *b*, Vect< T\_ > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< T\_ > &b, Vect< T\_ > &x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

### 7.34.4 Member Data Documentation

**LocalVect<T\_,NEE\_> ePrev** [inherited]

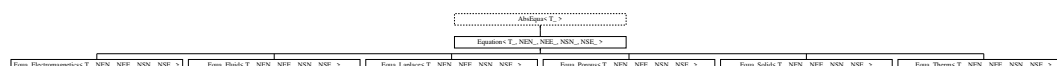
[LocalVect](#) instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.35 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)  
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** (**SkMatrix**< 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** (**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 [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.*

  - void [setMatrixType](#) (int t)
- Choose type of matrix.*

  - int [solveLinearSystem](#) ([Matrix](#)< T\_ > \*A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system with given matrix and right-hand side.*

  - int [solveLinearSystem](#) ([Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)
- Solve the linear system with given right-hand side.*

## 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.

### 7.35.1 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

Author

Rachid Touzani

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### 7.35.2 Constructor & Destructor Documentation

`Equation ( )`

Default constructor. Constructs an "empty" equation

`Equation ( Mesh & mesh )`

Constructor with mesh instance.

Parameters

in	<i>mesh</i>	<a href="#">Mesh</a> 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>	<a href="#">Mesh</a> instance
in	<i>b</i>	<a href="#">Vect</a> 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)

### 7.35.3 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. <i>dof</i> 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 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 )**

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 yhe 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> 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 )**

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 ( )**

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

<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 )**

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 SideAssembly ( PETScMatrix< T\_ > & A )**

Assemble side matrix into global one.

Parameters

<i>A</i>	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

<i>b</i>	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

<i>b</i>	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

<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 )**

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 )**

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 )**

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 )**

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\_ > \* 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\_ > & A )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>A</code>	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 )**

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>in</code>	<code>A</code>	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

<code>in</code>	<code>A</code>	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

<code>in</code>	<code>A</code>	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<sub>1</sub> > \* 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<sub>1</sub> > & 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<sub>1</sub> > & A )**

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<sub>1</sub> > & A )**

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 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	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>

**void setMatrixType ( int  $t$  )** [inherited]

Choose type of matrix.

Parameters

in	$t$	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	-----	---

**int solveLinearSystem ( Matrix< T\_ > \*  $A$ , Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$  )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	$A$	Pointer to matrix of the system
in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

**int solveLinearSystem ( Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$  )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

### 7.35.4 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

## 7.36 Estimator Class Reference

To calculate an a posteriori estimator of the solution.

### Public Types

### Public Member Functions

- [Estimator](#) ()  
*Default Constructor.*
- [Estimator](#) ([Mesh](#) & $m$ )  
*Constructor using finite element mesh.*
- [~Estimator](#) ()

*Destructor.*

- void `setType` (`EstimatorType` `t=ESTIM_ZZ`)  
*Select type of a posteriori estimator.*
- void `setSolution` (`const Vect< real.t > &u`)  
*Provide solution vector in order to determine error index.*
- void `getElementWiseIndex` (`Vect< real.t > &e`)  
*Get vector containing elementwise error index.*
- `real.t` `getAverage` () `const`  
*Return averaged error.*
- `Mesh &` `getMesh` () `const`  
*Return a reference to the finite element mesh.*

### 7.36.1 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.

Author

Rachid Touzani

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### 7.36.2 Member Enumeration Documentation

**enum** `EstimatorType`

Enumerate variable that selects an error estimator for mesh adaptation purposes

Enumerator

`ESTIM_ZZ` Zhu-Zienkiewicz elementwise estimator

`ESTIM_ND_JUMP` Normal derivative jump sidewise estimator

### 7.36.3 Constructor & Destructor Documentation

**Estimator** ( `Mesh & m` )

Constructor using finite element mesh.

Parameters

in	<code>m</code>	<code>Mesh</code> instance
----	----------------	----------------------------

### 7.36.4 Member Function Documentation

**void** `setType` ( `EstimatorType` `t = ESTIM_ZZ` )

Select type of a posteriori estimator.

Parameters

in	$t$	Type of estimator. It has to be chosen among the enumerated values: <ul style="list-style-type: none"> <li>• ESTIM_ZZ: The Zhu-Zienckiewicz estimator (Default value)</li> <li>• ESTIM_ND_JUMP: An estimator based on the jump of normal derivatives of the solution across mesh sides</li> </ul>
----	-----	---

**void setSolution ( const Vect< real.t > &  $u$  )**

Provide solution vector in order to determine error index.

Parameters

in	$u$	Vector containing solution at mesh nodes
----	-----	--

**void getElementWiseIndex ( Vect< real.t > &  $e$  )**

Get vector containing elementwise error index.

Parameters

in,out	$e$	Vector that contains once the member function setError is invoked a posteriori estimator at each element
--------	-----	--

## 7.37 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.*

### 7.37.1 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.

Author

M. Sylla, B. Meden

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### 7.37.2 Constructor & Destructor Documentation

**FastMarching2D ( const Grid & *g*, Vect< real\_t > & *ls* )**

Constructor using grid and level set function.

Parameters

in	<i>g</i>	Instance of class <a href="#">Grid</a>
in	<i>ls</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.

**FastMarching2D ( const Grid & *g*, Vect< real\_t > & *ls*, Vect< real\_t > & *F* )**

Constructor using grid, level set function and velocity to extend.

Parameters

in	<i>g</i>	Instance of class <a href="#">Grid</a>
in	<i>ls</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 their sign is right.
in	<i>F</i>	Vector containing the front speed at grid nodes. Only values on nodes surrounding the interface are relevant.

### 7.37.3 Member Function Documentation

**void execute ( )**

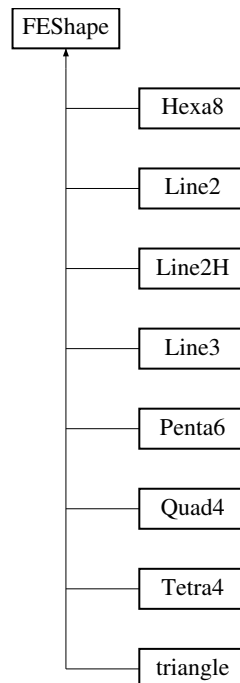
Execute Fast Marching Procedure.

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.

## 7.38 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.*

### 7.38.1 Detailed Description

Parent class from which inherit all finite element shape classes.

Author

Rachid Touzani

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### 7.38.2 Constructor & Destructor Documentation

**FEShape ( const Element \* *el* )**

Constructor for an element.

Parameters

in	<i>el</i>	Pointer to element
----	-----------	--------------------

**FEShape ( const Side \* *sd* )**

Constructor for a side.

Parameters

in	<i>sd</i>	Pointer to side
----	-----------	-----------------

### 7.38.3 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>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**

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**

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**

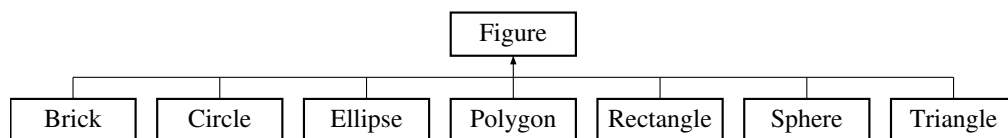
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.39 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.*

### 7.39.1 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.

Author

Rachid Touzani

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### 7.39.2 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

## 7.40 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.*
- **FMM2D** (const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &phi, const [Vect](#)< [real\\_t](#) > &F, bool HA)  
*Constructor.*
- void **init** ()  
*Initialize the heap.*
- void **run** ()  
*Execute Fast Marching Procedure.*
- void **eval** (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.*

### 7.40.1 Detailed Description

class for the fast marching 2-D algorithm

This class manages the 2-D Fast Marching method

Author

M. Sylla, B. Meden

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### 7.40.2 Constructor & Destructor Documentation

**FMM2D** ( const [Grid](#) &g, [Vect](#)< [real\\_t](#) > &phi, bool HA )

Constructor.

Constructor using [Grid](#) instance

Parameters

in	g	Instance of class <a href="#">Grid</a>
----	---	--

## Parameters

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

**FMM2D ( const Grid &g, Vect< real.t > &phi, const Vect< real.t > &F, bool HA )**

## Constructor.

Constructor using [Grid](#) instance

## 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>F</i>	Right hand-side of the Eikonal equation
in	<i>HA</i>	true if the program must be executed with high accuracy, false otherwise

### 7.40.3 Member Function Documentation

**void eval ( 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

**7.41 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.*
- **FMM3D** (const [Grid](#) &g, [Vect](#)< [real.t](#) > &phi, const [Vect](#)< [real.t](#) > &F, bool HA)  
*Constructor.*
- void **init** ()  
*Initialize heap.*
- void **run** ()  
*Execute Fast Marching Procedure.*
- void **eval** (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.*

**7.41.1 Detailed Description**

class for the 3-D fast marching algorithm  
This class manages the 3-D Fast Marching Method

**7.41.2 Constructor & Destructor Documentation**

**FMM3D ( const [Grid](#) &g, [Vect](#)< [real.t](#) > &phi, bool HA )**

Constructor.  
Constructor using [Grid](#) instance

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

## Author

M. Sylla, B. Meden

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**FMM3D ( const Grid &g, Vect< real.t > &phi, const Vect< real.t > &F, bool HA )**

## Constructor.

Constructor using [Grid](#) instance

## 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>F</i>	Vector containing the right-hand side of the Eikonal equation
in	<i>HA</i>	true if the program must be executed with high accuracy, false otherwise

## Author

M. Sylla, B. Meden

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### 7.41.3 Member Function Documentation

**void eval ( IPoint &pt, int sign )**

Compute the distance from node to interface.

## Parameters

in	<i>pt</i>	Node to treat
in	<i>sign</i>	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

## 7.42 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 **run** ()  
*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.*

### 7.42.1 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

Author

M. Sylla, B. Meden

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### 7.42.2 Constructor & Destructor Documentation

**FMMSolver** ( const [Grid](#) &g, [Vect](#)< [real.t](#) > &phi, bool ha = false )

Constructor.

Parameters

in	g	Instance of class <a href="#">Grid</a> defining the grid on which the distance is computed.
----	---	---

Parameters

in	<i>phi</i>	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	<i>ha</i>	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.

### 7.42.3 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	<i>F</i>	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.

## 7.43 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 =.*

### 7.43.1 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)
```

Author

Rachid Touzani

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### 7.43.2 Constructor & Destructor Documentation

**Funct ( string  $v$  )**

Constructor for a function of one variable.

Parameters

in	$v$	Name of the variable
----	-----	----------------------

**Funct ( string  $v1$ , string  $v2$  )**

Constructor for a function of two variables.

Parameters

in	$v1$	Name of the first variable
in	$v2$	Name of the second variable



**Func**( `string v1`, `string v2`, `string v3` )

Constructor for a function of three variables.

Parameters

in	<i>v1</i>	Name of the first variable
in	<i>v2</i>	Name of the second variable
in	<i>v3</i>	Name of the third variable

**Func**( `string v1`, `string v2`, `string v3`, `string v4` )

Constructor for a function of four variables.

Parameters

in	<i>v1</i>	Name of the first variable
in	<i>v2</i>	Name of the second variable
in	<i>v3</i>	Name of the third variable
in	<i>v4</i>	Name of the fourth variable

### 7.43.3 Member Function Documentation

**void operator=**( `string e` )

Operator =.

Define the function by an algebraic expression following regexp rules

Parameters

in	<i>e</i>	Algebraic expression defining the function.
----	----------	---

## 7.44 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 [setNbPoints](#) (size\_t np)  
*Set number of integration 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.*

### 7.44.1 Detailed Description

Calculate data for Gauss integration.

Author

Rachid Touzani

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### 7.44.2 Constructor & Destructor Documentation

**Gauss ( size.t np )**

Constructor using number of Gauss points.

Parameters

in	<i>np</i>	Number of integration points
----	-----------	------------------------------

### 7.44.3 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.

Parameters

out	<i>w</i>	Array of weights of integration points
out	<i>x</i>	Array of coordinates of integration points

## 7.45 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 np)`

*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** np<sub>x</sub>, **size.t** np<sub>y</sub>)  
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** np<sub>x</sub>, **size.t** np<sub>y</sub>)  
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** np<sub>x</sub>, **size.t** np<sub>y</sub>, **size.t** np<sub>z</sub>)  
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** np<sub>x</sub>, **size.t** np<sub>y</sub>, **size.t** np<sub>z</sub>)  
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)*

### 7.45.1 Detailed Description

To manipulate structured grids.

Author

Rachid Touzani

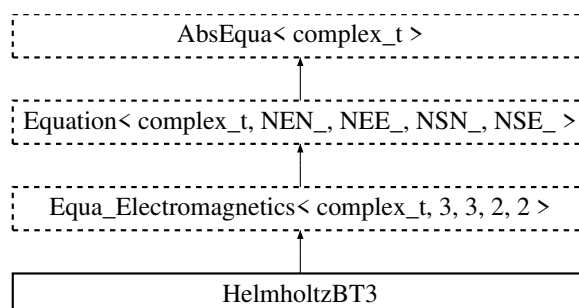
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## 7.46 HelmholtzBT3 Class Reference

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](#)< [complex\\_t](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [complex\\_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](#)< [complex\\_t](#) > &b)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [complex\\_t](#) > &b, [LocalVect](#)< [complex\\_t](#), NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [complex\\_t](#) > &b, [LocalVect](#)< [complex\\_t](#), NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [complex\\_t](#) > &b, [LocalVect](#)< [complex\\_t](#), NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [complex\\_t](#) > &b, [LocalVect](#)< [complex\\_t](#), NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*

- void `ElementVector` (const `Vect< complex_t >` &b, int dof\_type=NODE\_FIELD, int flag=0)  
*Localize Element Vector.*
- void `SideVector` (const `Vect< complex_t >` &b)  
*Localize Side Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()  
*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix< complex_t >` \*A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScVect< complex_t >` &b)  
*Assemble element right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SpMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`TrMatrix< complex_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`Vect< complex_t >` &v)  
*Assemble element vector into global one.*
- void `SideAssembly` (`PETScMatrix< complex_t >` &A)  
*Assemble side matrix into global one.*
- void `SideAssembly` (`PETScVect< complex_t >` &b)  
*Assemble side right-hand side vector into global one.*
- void `SideAssembly` (`Matrix< complex_t >` \*A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkSMatrix< complex_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkMatrix< complex_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SpMatrix< complex_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`Vect< complex_t >` &v)  
*Assemble side (edge or face) vector into global one.*
- void `DGElementAssembly` (`Matrix< complex_t >` \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkSMatrix< complex_t >` &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkMatrix< complex_t >` &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

- void **DGElementAssembly** (**SpMatrix**< **complex.t** > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **DGElementAssembly** (**TrMatrix**< **complex.t** > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **AxbAssembly** (const **Element** &el, const **Vect**< **complex.t** > &x, **Vect**< **complex.t** > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void **AxbAssembly** (const **Side** &sd, const **Vect**< **complex.t** > &x, **Vect**< **complex.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**< **complex.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**< **complex.t** > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=IDENT\_PREC)  
*Choose solver for the linear system.*
- void **setMatrixType** (int t)  
*Choose type of matrix.*
- int **solveLinearSystem** (**Matrix**< **complex.t** > \*A, **Vect**< **complex.t** > &b, **Vect**< **complex.t** > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (**Vect**< **complex.t** > &b, **Vect**< **complex.t** > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.46.1 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.

Author

Rachid Touzani

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### 7.46.2 Member Function Documentation

**void updateBC ( const [Element](#) &el, const [Vect](#)< [complex\\_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](#)< [complex\\_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>• <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>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< complex.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 <code>Element</code> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< complex.t > &*b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.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< complex.t > & *b*, LocalVect< complex.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< complex.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< complex.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< complex.t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes SkSMatrix, SkMatrix, SpMatrix)
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< complex.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< complex.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< complex.t > & A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< complex.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< complex.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< complex.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< complex.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< complex.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< complex.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< complex.t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< complex.t > &v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< complex.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< complex.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< complex.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< complex.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.



Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< complex.t > &A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element &el, const Vect< complex.t > &x, Vect< complex.t > &b )** [inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	$el$	Reference to Element instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector to add (Vect instance)

**void AxbAssembly ( const Side &sd, const Vect< complex.t > &x, Vect< complex.t > &b )** [inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	$sd$	Reference to Side instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< complex\_t > \* *A*, Vect< complex\_t > & *b*, Vect< complex\_t > & *x* )** [inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< complex\_t > & *b*, Vect< complex\_t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

### 7.46.3 Member Data Documentation

**LocalVect<complex\_t,NEE\_> ePrev** [inherited]

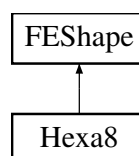
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.47 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.*

### 7.47.1 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.

Author

Rachid Touzani

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### 7.47.2 Member Function Documentation

**void setLocal ( const Point< real\_t > & s )**

Initialize local point coordinates in element.

Parameters

in	s	Point 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 )**

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.

**void atGauss1 ( LocalVect< Point< real\_t >, 8 > & dsh, real\_t & w )**

Calculate shape function derivatives and integration weights for 1-point Gauss rule.

Parameters

in	dsh	Vector of shape function derivatives at the Gauss point
in	w	Weight of integration formula at Gauss point

**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.

Parameters

in	dsh	Vector of shape function derivatives at the Gauss points
in	w	Weights of integration formula at Gauss points

**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	Point 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]

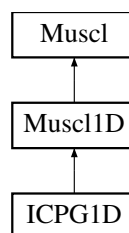
Localize a point in the element.

Return actual coordinates where `s` are coordinates in the reference element.

## 7.48 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

### 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  $C_v$  (specific heat at constant volume)*
- `void setCp (real_t Cp)`  
*Set value of  $C_p$  (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  $C_v$  (specific heat at constant volume)*
- `real_t getCp () const`  
*Return value of  $C_p$  (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.*



### 7.48.1 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

Author

S. Clain, V. Clauzon

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### 7.48.2 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

### 7.48.3 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

#### 7.48.4 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 code

**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>	Side instance to which the values are assigned
in	<i>u</i>	LocalVect 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>	Side code for which the values are assigned
in	<i>U</i>	LocalVect 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>	LocalVect 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

in	<i>sd</i>	Instance of Side on which the condition is prescribed
in	<i>u</i>	LocalVect 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

in	<i>code</i>	Value of code for which the condition is prescribed
in	<i>u</i>	LocalVect 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

in	<i>u</i>	LocalVect instance that contains values to assign to the sides
----	----------	--

**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
----	----------	------------------------------

**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

---

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.

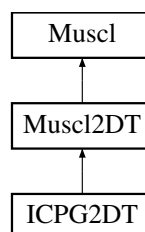
Parameters

in	$l$	Limiter to choose
----	-----	-------------------

## 7.49 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

### 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.*



### 7.49.1 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

Author

S. Clain, V. Clauzon

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### 7.49.2 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

### 7.49.3 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> )

#### 7.49.4 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 ( <i>x</i> , <i>vx</i> , <i>vy</i> , <i>p</i> )

**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 ( <i>x</i> , <i>vx</i> , <i>vy</i> , <i>p</i> )

**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 ( <i>x</i> , <i>vx</i> , <i>vy</i> , <i>p</i> )
----	----------	---

**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	<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], [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	<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.

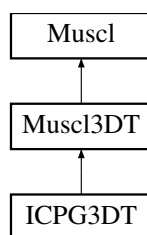
Parameters

in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.50 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

## 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.*

### 7.50.1 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

Author

S. Clain, V. Clauzon

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### 7.50.2 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

### 7.50.3 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> )

### 7.50.4 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
----	----------	----------------------

Parameters

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	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.51 IOField Class Reference

Enables working with files in the XML Format.

Inherits XMLParser.

### Public Types

### 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** (const string &file, **AccessType** access, const string &name)  
*Constructor using file name and field name.*
- **~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, const string &name)  
*Get Vect v instance from file if the field has the given name.*
- int **get** (**DMatrix**< **real\_t** > &A, const string &name)  
*Get DMatrix A instance from file if the field has the given name.*
- int **get** (**DSMatrix**< **real\_t** > &A, const string &name)  
*Get DSMatrix A instance from file if the field has the given name.*
- 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.*

### 7.51.1 Detailed Description

Enables working with files in the XML Format.

This class has methods to store vectors in files and read from files.

Author

Rachid Touzani

Copyright

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## 7.52 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.*

### 7.52.1 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

Author

Rachid Touzani

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### 7.52.2 Constructor & Destructor Documentation

**IPF ( const string &file )**

Constructor that gives the data file name.

It reads parameters in [IPF](#) Format from this file.

### 7.52.3 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

in	<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

in	<i>label</i>	Label that identifies the string (read from input file)
in	<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

in	<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

in	<i>label</i>	Label that identifies the integer number (read from input file).
in	<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

in	<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

in	<i>label</i>	Label that identifies the real number (read from input file)
in	<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

in	<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

in	<i>label</i>	Label that identifies the complex number (read from input file)
in	<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

in	<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

in	<i>label</i>	Label that identifies the array (read from input file).
in	<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 getBFFFile ( ) const**

Return parameter read using keyword **BFFFile**.  
This parameter can be used to read a body force file name.

**string getSFFFile ( ) const**

Return parameter read using keyword **SFFFile**.  
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

## 7.53 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.*
- bool [check](#) (T\_ &u, const T\_ &v)  
*Check convergence for a scalar case (one equation)*

### 7.53.1 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.

Author

Rachid Touzani

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### 7.53.2 Member Function Documentation

**void setMaxIter ( int *max\_it* )**

Set maximal number of iterations.

Parameters

in	<i>max_it</i>	Maximal number of iterations [Default: 100]
----	---------------	---

**void setTolerance ( real\_t *toler* )**

Set tolerance value for convergence.

Parameters

in	<i>toler</i>	Tolerance value [Default: 1.e-8]
----	--------------	----------------------------------

**void setVerbose ( int *v* )**

Set verbosity parameter.

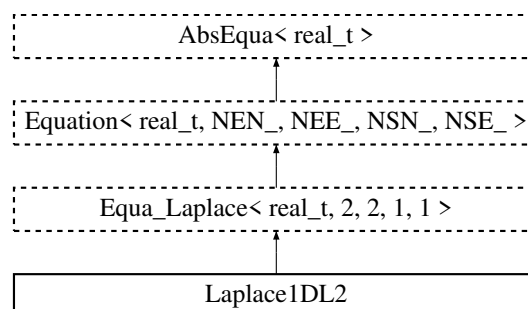
Parameters

in	<i>v</i>	Verbosity parameter [Default: 0]
----	----------	----------------------------------

## 7.54 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](#) ()  
*Default constructor.*
- [Laplace1DL2](#) ([Element](#) \*el)  
*Constructor for an element.*
- [Laplace1DL2](#) ([Mesh](#) &ms, [Vect](#)< [real\\_t](#) > &u)
- [Laplace1DL2](#) ([Mesh](#) &ms)
- [~Laplace1DL2](#) ()  
*Destructor.*
- void [LHS](#) ([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](#) (const [Vect](#)< [real\\_t](#) > &f)  
*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](#) ()  
*Build and solve the linear system of equations using an iterative method.*
- void [build](#) ()  
*Build global matrix and right-hand side.*
- 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](#)< [real\\_t](#) > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< [real\\_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](#)< [real\\_t](#) > &b)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEN\\_](#) > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEN\\_](#) > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NSE\\_](#) > &be)  
*Localize Element Vector from a Vect instance.*
- void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*

- void `SideVector` (const `Vect< real_t >` &b)  
*Localize Side Vector.*
- void `ElementNodeCoordinates` ()  
*Localize coordinates of element nodes.*
- void `SideNodeCoordinates` ()  
*Localize coordinates of side nodes.*
- void `ElementAssembly` (`Matrix< real_t >` \*A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`PETScVect< real_t >` &b)  
*Assemble element right-hand side vector into global one.*
- void `ElementAssembly` (`BMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkSMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SkMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`SpMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`TrMatrix< real_t >` &A)  
*Assemble element matrix into global one.*
- void `ElementAssembly` (`Vect< real_t >` &v)  
*Assemble element vector into global one.*
- void `SideAssembly` (`PETScMatrix< real_t >` &A)  
*Assemble side matrix into global one.*
- void `SideAssembly` (`PETScVect< real_t >` &b)  
*Assemble side right-hand side vector into global one.*
- void `SideAssembly` (`Matrix< real_t >` \*A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkSMatrix< real_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SkMatrix< real_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`SpMatrix< real_t >` &A)  
*Assemble side (edge or face) matrix into global one.*
- void `SideAssembly` (`Vect< real_t >` &v)  
*Assemble side (edge or face) vector into global one.*
- void `DGElementAssembly` (`Matrix< real_t >` \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkSMatrix< real_t >` &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SkMatrix< real_t >` &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void `DGElementAssembly` (`SpMatrix< real_t >` &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*



- void **DGElementAssembly** (**TrMatrix**< **real.t** > &**A**)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void **AxbAssembly** (const **Element** &**el**, const **Vect**< **real.t** > &**x**, **Vect**< **real.t** > &**b**)  
*Assemble product of element matrix by element vector into global vector.*
- void **AxbAssembly** (const **Side** &**sd**, const **Vect**< **real.t** > &**x**, **Vect**< **real.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**< **real.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**< **real.t** > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** **ls**, **Preconditioner** **pc**=**IDENT\_PREC**)  
*Choose solver for the linear system.*
- void **setMatrixType** (int **t**)  
*Choose type of matrix.*
- int **solveLinearSystem** (**Matrix**< **real.t** > \***A**, **Vect**< **real.t** > &**b**, **Vect**< **real.t** > &**x**)  
*Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (**Vect**< **real.t** > &**b**, **Vect**< **real.t** > &**x**)  
*Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.54.1 Detailed Description

To build element equation for a 1-D elliptic equation using the 2-Node line element ( $P_1$ ).

Author

Rachid Touzani

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### 7.54.2 Constructor & Destructor Documentation

**Laplace1DL2 ( Mesh & *ms*, Vect< real.t > & *u* )**

Constructor using mesh instance and solution vector

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in,out	<i>u</i>	<a href="#">Vect</a> instance that contains, after execution of <a href="#">run()</a> the solution

**Laplace1DL2 ( Mesh & *ms* )**

Constructor using mesh instance

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

### 7.54.3 Member Function Documentation

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

Add finite element matrix to left hand side.

Parameters

in	<i>coef</i>	Value to multiply by the added matrix
----	-------------	---------------------------------------

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

**void BodyRHS ( const Vect< real.t > &f )** [virtual]

Add Right-Hand Side Contribution.

Parameters

in	<i>f</i>	Vector containing the source given function at mesh nodes
----	----------	---

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

**void BoundaryRHS ( const Vect< real.t > &f )** [virtual]

Add Neumann contribution to Right-Hand Side.

Parameters

in	<i>f</i>	Vector with size the total number of nodes. The first entry stands for the force at the first node (Neumann condition) and the last entry is the force at the last node (Neumann condition)
----	----------	---

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

**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 ( )** [inherited]

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (eps=-1) or the GMRES method if not. The solution is stored in the vector u given in the constructor.

Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is 1.e-8

**void build ( )** [inherited]

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.

**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< real.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< real.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>
----	-----------------	--

## Parameters

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. <i>dof</i> is handled in the system</li> </ul>
----	------------	---

**void LocalNodeVector ( Vect< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---



**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	A	Global matrix stored as an SkMatrix instance
----	---	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	A	Global matrix stored as an SpMatrix instance
----	---	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	A	Global matrix stored as an TrMatrix instance
----	---	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real\_t > &v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	A	Global matrix stored as an SkMatrix instance
----	---	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	A	Global matrix stored as an SpMatrix instance
----	---	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

**Parameters**

in	v	Global vector (Vect instance)
----	---	-------------------------------

**Warning**

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real\_t > & b, Vect< real\_t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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<real\_t,NEE-> ePrev** [inherited]

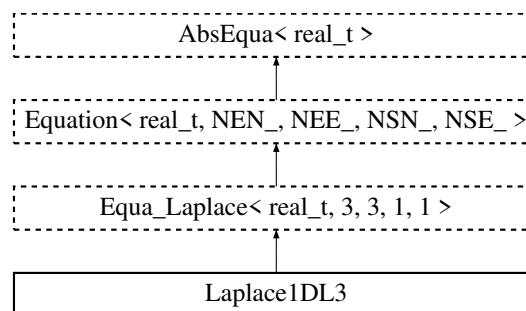
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.55 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 \(Mesh &ms\)](#)
- [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 \(const Vect< real\\_t > &h\)](#)  
*Add Neumann contribution to Right-Hand Side.*
- void [setTraction \(real\\_t f, int lr\)](#)  
*Set Traction data.*
- virtual void [LHS \(real\\_t coef=1.\)](#)

- Add finite element matrix to left-hand side.*

  - `int run ()`

*Build and solve the linear system of equations using an iterative method.*
- `void build ()`

*Build global matrix and right-hand side.*
- `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< real_t > &bc)`

*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< real_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< real_t > &b)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< real_t > &b, LocalVect< real_t, NEE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< real_t > &b, LocalVect< real_t, NEN_ > &be, int dof)`

*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< real_t > &b, LocalVect< real_t, NEN_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< real_t > &b, LocalVect< real_t, NSE_ > &be)`

*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< real_t > &b, int dof_type=NODE.FIELD, int flag=0)`

*Localize Element Vector.*
- `void SideVector (const Vect< real_t > &b)`

*Localize Side Vector.*
- `void ElementNodeCoordinates ()`

*Localize coordinates of element nodes.*
- `void SideNodeCoordinates ()`

*Localize coordinates of side nodes.*
- `void ElementAssembly (Matrix< real_t > *A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (PETScMatrix< real_t > &A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (PETScVect< real_t > &b)`

*Assemble element right-hand side vector into global one.*
- `void ElementAssembly (BMatrix< real_t > &A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (SkSMatrix< real_t > &A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (SkMatrix< real_t > &A)`

*Assemble element matrix into global one.*
- `void ElementAssembly (SpMatrix< real_t > &A)`



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

*Return reference to linear solver instance.*

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

*Choose solver for the linear system.*

- void `setMatrixType` (int t)

*Choose type of matrix.*

- int `solveLinearSystem` (Matrix< real.t > \*A, Vect< real.t > &b, Vect< real.t > &x)

*Solve the linear system with given matrix and right-hand side.*

- int `solveLinearSystem` (Vect< real.t > &b, Vect< real.t > &x)

*Solve the linear system with given right-hand side.*

## Public Attributes

- LocalMatrix< real.t, NEE\_, NEE\_ > `eMat`

*LocalMatrix instance containing local matrix associated to current element.*

- LocalMatrix< real.t, NSE\_, NSE\_ > `sMat`

*LocalMatrix instance containing local matrix associated to current side.*

- LocalVect< real.t, NEE\_ > `ePrev`

*LocalVect instance containing local vector associated to current element.*

- LocalVect< real.t, NEE\_ > `eRHS`

*LocalVect instance containing local right-hand side vector associated to current element.*

- LocalVect< real.t, NEE\_ > `eRes`

*LocalVect instance containing local residual vector associated to current element.*

- LocalVect< real.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.*

### 7.55.1 Detailed Description

To build element equation for the 1-D elliptic equation using the 3-Node line ( $P_2$ ).

Author

Rachid Touzani

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### 7.55.2 Constructor & Destructor Documentation

Laplace1DL3 ( Mesh & ms )

Constructor using mesh instance

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

**Laplace1DL3 ( Mesh & *ms*, Vect< real.t > & *u* )**

Constructor using mesh instance and solution vector

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in,out	<i>u</i>	<a href="#">Vect</a> instance that contains, after execution of <a href="#">run()</a> the solution

### 7.55.3 Member Function Documentation

**void Matrix ( 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* ) [virtual]**

Add Right-hand side contribution.

Parameters

in	<i>f</i>	Vector of right-hand side of the Poisson equation at nodes
----	----------	--

Reimplemented from [Equa.Laplace< real.t, 3, 3, 1, 1 >](#).

**void BoundaryRHS ( const Vect< real.t > & *h* ) [virtual]**

Add Neumann contribution to Right-Hand Side.

Parameters

in	<i>h</i>	Vector with size the total number of nodes. The first entry stands for the force at the first node (Neumann condition) and the last entry is the force at the last node (Neumann condition)
----	----------	---

Reimplemented from [Equa.Laplace< real.t, 3, 3, 1, 1 >](#).

**void setTraction ( real.t *f*, int *lr* )**

Set Traction data.

Parameters

in	$f$	Value of traction (Neumann boundary condition)
in	$lr$	Option to choose location of the traction (-1: Left end, 1: Right end)

**virtual void LHS ( real\_t coef = 1. )** [virtual], [inherited]

Add finite element matrix to left-hand side.

Parameters

in	$coef$	Value to multiply by the added matrix
----	--------	---------------------------------------

**int run ( )** [inherited]

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite ( $eps=-1$ ) or the GMRES method if not. The solution is stored in the vector  $u$  given in the constructor.

Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is  $1.e-8$

**void build ( )** [inherited]

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.

**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< real\_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< real.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>• <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>dof</i>	DOF setting: <ul style="list-style-type: none"> <li>• <i>= 0</i>, All DOFs are taken into account [Default]</li> <li>• <i>!= 0</i>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>

**void LocalNodeVector ( Vect< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real.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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes SkSMatrix, SkMatrix, SpMatrix)
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.



Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real.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< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & *v* )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element &  $el$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	$el$	Reference to Element instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector to add (Vect instance)

**void AxbAssembly ( const Side &  $sd$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	$sd$	Reference to Side instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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<real.t,NEE\_> ePrev** [inherited]

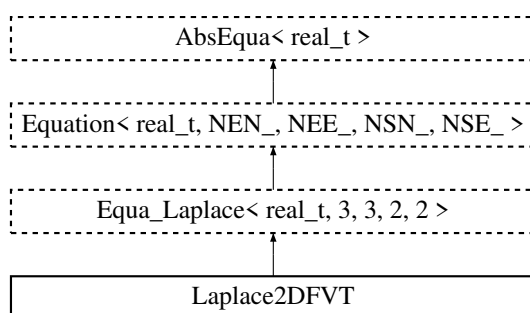
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.56 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 LHS** (**real\_t** coef=1.)  
*Calculate left-hand side.*
- **void RHS** (const **Vect**< **real\_t** > &f)  
*Add right-hand side Contribution.*
- **virtual void BodyRHS** (const **Vect**< **real\_t** > &f)  
*Add body source term to right-hand side.*
- **virtual void BoundaryRHS** (const **Vect**< **real\_t** > &h)  
*Add boundary source term to right-hand side.*
- **int run** ()  
*Build and solve the linear system of equations using an iterative method.*
- **void build** ()  
*Build global matrix and right-hand side.*
- **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**< **real\_t** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- **void updateBC** (const **Vect**< **real\_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](#)< [real\\_t](#) > &b)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEE\_ > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be, int dof)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NSE\_ > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)

*Localize Element Vector.*
- void [SideVector](#) (const [Vect](#)< [real\\_t](#) > &b)

*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()

*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()

*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)

*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< [real\\_t](#) > &v)

*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)

*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)

*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)

- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly (SpMatrix< real.t > &A)`
- Assemble side (edge or face) matrix into global one.*
  - void `SideAssembly (Vect< real.t > &v)`
- Assemble side (edge or face) vector into global one.*
  - void `DGElementAssembly (Matrix< real.t > *A)`
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly (SkMatrix< real.t > &A)`
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly (SkMatrix< real.t > &A)`
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly (SpMatrix< real.t > &A)`
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void `DGElementAssembly (TrMatrix< real.t > &A)`
- Assemble product of element matrix by element vector into global vector.*
  - void `AxbAssembly (const Element &el, const Vect< real.t > &x, Vect< real.t > &b)`
- Assemble product of side matrix by side vector into global vector.*
  - void `AxbAssembly (const Side &sd, const Vect< real.t > &x, Vect< real.t > &b)`
- Return number of element nodes.*
  - size\_t `getNbNodes ()` const
- Return number of element equations.*
  - size\_t `getNbEq ()` const
- Set initial solution (previous time step)*
  - void `setInitialSolution (const Vect< real.t > &u)`
- Define a material property by an algebraic expression.*
  - real.t `setMaterialProperty (const string &exp, const string &prop)`
- Define mesh and renumber DOFs after removing imposed ones.*
  - void `setMesh (Mesh &m)`
- Return reference to Mesh instance.*
  - Mesh & `getMesh ()` const
- Return reference to linear solver instance.*
  - LinearSolver< real.t > & `getLinearSolver ()`
- Choose solver for the linear system.*
  - void `setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`
- Choose type of matrix.*
  - void `setMatrixType (int t)`
- Solve the linear system with given matrix and right-hand side.*
  - int `solveLinearSystem (Matrix< real.t > *A, Vect< real.t > &b, Vect< real.t > &x)`
- Solve the linear system with given right-hand side.*
  - int `solveLinearSystem (Vect< real.t > &b, Vect< real.t > &x)`

## Public Attributes

- [LocalMatrix](#)< [real.t](#), [NEE\\_](#), [NEE\\_](#) > [eMat](#)  
*LocalMatrix instance containing local matrix associated to current element.*
- [LocalMatrix](#)< [real.t](#), [NSE\\_](#), [NSE\\_](#) > [sMat](#)  
*LocalMatrix instance containing local matrix associated to current side.*
- [LocalVect](#)< [real.t](#), [NEE\\_](#) > [ePrev](#)  
*LocalVect instance containing local vector associated to current element.*
- [LocalVect](#)< [real.t](#), [NEE\\_](#) > [eRHS](#)  
*LocalVect instance containing local right-hand side vector associated to current element.*
- [LocalVect](#)< [real.t](#), [NEE\\_](#) > [eRes](#)  
*LocalVect instance containing local residual vector associated to current element.*
- [LocalVect](#)< [real.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.*

### 7.56.1 Detailed Description

To build and solve the Laplace equation using a standard Finite Volume method.

Author

Rachid Touzani

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### 7.56.2 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 ELEMENT_DOF 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

### 7.56.3 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

**virtual void BodyRHS ( const Vect< real\_t > &*f* )** [virtual], [inherited]

Add body source term to right-hand side.

Parameters

in	<i>f</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#).

**virtual void BoundaryRHS ( const Vect< real\_t > &*h* )** [virtual], [inherited]

Add boundary source term to right-hand side.

Parameters

in	<i>h</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#).

**int run ( )** [inherited]

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (eps=-1) or the GMRES method if not. The solution is stored in the vector *u* given in the constructor.

## Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is 1.e-8

**void build ( )** [inherited]

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.

**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< real\_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< real\_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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--



## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem** ( **Vect**< **real.t** > &*b*, **Vect**< **real.t** > &*x* ) [inherited]

Solve the linear system with given right-hand side.

Parameters

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

## 7.56.4 Member Data Documentation

**LocalVect**<**real.t**,**NEE\_**> **ePrev** [inherited]

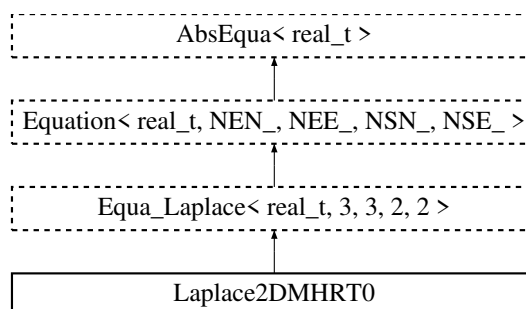
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.57 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.*
- virtual void **LHS** (**real.t** coef=1.)  
*Add finite element matrix to left-hand side.*
- virtual void **BodyRHS** (const **Vect**< **real.t** > &f)  
*Add body source term to right-hand side.*
- virtual void **BoundaryRHS** (const **Vect**< **real.t** > &h)  
*Add boundary source term to right-hand side.*
- int **run** ()  
*Build and solve the linear system of equations using an 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**< **real.t** > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const **Vect**< **real.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**< **real.t** > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEE\_** > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEN\_** > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NEN\_** > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const **Vect**< **real.t** > &b, **LocalVect**< **real.t**, **NSE\_** > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const **Vect**< **real.t** > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const **Vect**< **real.t** > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*
- void **SideNodeCoordinates** ()  
*Localize coordinates of side nodes.*
- void **ElementAssembly** (**Matrix**< **real.t** > \*A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScMatrix**< **real.t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**PETScVect**< **real.t** > &b)  
*Assemble element right-hand side vector into global one.*
- void **ElementAssembly** (**BMatrix**< **real.t** > &A)  
*Assemble element matrix into global one.*
- void **ElementAssembly** (**SkSMatrix**< **real.t** > &A)

- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) (Vect< real.t > &v)
- Assemble element vector into global one.*
  - void [SideAssembly](#) (PETScMatrix< real.t > &A)
- Assemble side matrix into global one.*
  - void [SideAssembly](#) (PETScVect< real.t > &b)
- Assemble side right-hand side vector into global one.*
  - void [SideAssembly](#) (Matrix< real.t > \*A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SkSMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SkMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (SpMatrix< real.t > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) (Vect< real.t > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) (Matrix< real.t > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SkSMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SkMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (SpMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) (TrMatrix< real.t > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const Vect< real.t > &x, Vect< real.t > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const Vect< real.t > &x, Vect< real.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< real.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< real_t > & getLinearSolver ()`

*Return reference to linear solver instance.*

- void `setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`

*Choose solver for the linear system.*

- void `setMatrixType (int t)`

*Choose type of matrix.*

- int `solveLinearSystem (Matrix< real_t > *A, Vect< real_t > &b, Vect< real_t > &x)`

*Solve the linear system with given matrix and right-hand side.*

- int `solveLinearSystem (Vect< real_t > &b, Vect< real_t > &x)`

*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`

*LocalMatrix instance containing local matrix associated to current element.*

- `LocalMatrix< real_t, NSE_, NSE_ > sMat`

*LocalMatrix instance containing local matrix associated to current side.*

- `LocalVect< real_t, NEE_ > ePrev`

*LocalVect instance containing local vector associated to current element.*

- `LocalVect< real_t, NEE_ > eRHS`

*LocalVect instance containing local right-hand side vector associated to current element.*

- `LocalVect< real_t, NEE_ > eRes`

*LocalVect instance containing local residual vector associated to current element.*

- `LocalVect< real_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.*

### 7.57.1 Detailed Description

To build element equation for the 2-D elliptic equation using the Mixed Hybrid finite element at lowest degree (Raviart-Thomas  $RT_0$ ).

Author

Rachid Touzani

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### 7.57.2 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

### 7.57.3 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	<i>K</i>	Diffusivity matrix as <a href="#">LocalMatrix</a> instance. Must be symmetric positive definite
----	----------	---

#### void build ( )

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.

#### 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>	<a href="#">Vect</a> instance containing the right-hand side of the Laplace equation
in	<i>v</i>	<a href="#">Vect</a> instance containing solution at mesh nodes
in	<i>p</i>	<a href="#">Vect</a> instance containing gradient at elements
in	<i>u</i>	<a href="#">Vect</a> instance 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

**virtual void LHS ( real\_t *coef* = 1. )** [virtual], [inherited]

Add finite element matrix to left-hand side.

Parameters

in	<i>coef</i>	Value to multiply by the added matrix
----	-------------	---------------------------------------

Reimplemented in [Laplace2DT3](#), and [Laplace2DFVT](#).

**virtual void BodyRHS ( const Vect< real\_t > & *f* )** [virtual], [inherited]

Add body source term to right-hand side.

Parameters

in	<i>f</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#).

**virtual void BoundaryRHS ( const Vect< real\_t > & *h* )** [virtual], [inherited]

Add boundary source term to right-hand side.

Parameters

in	<i>h</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented in [Laplace2DT3](#).

**int run ( )** [inherited]

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (*eps*=-1) or the GMRES method if not. The solution is stored in the vector *u* given in the constructor.

## Returns

Number of performed iterations. 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< real\_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< real\_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>
----	-----------------	--

Parameters

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. <i>dof</i> is handled in the system</li> </ul>
----	------------	---

**void LocalNodeVector ( Vect< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

**Parameters**

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

**Parameters**

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

**Warning**

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

**Parameters**

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

**Warning**

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > & A )** [inherited]

Assemble side matrix into global one.

**Parameters**

<i>A</i>	Reference to global matrix
----------	----------------------------

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > & b )** [inherited]

Assemble side right-hand side vector into global one.

**Parameters**

<i>b</i>	Reference to global right-hand side vector
----------	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

**Warning**

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

**Parameters**

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

#### Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

#### Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

#### Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

#### Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

#### Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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



**int solveLinearSystem ( Vect< real\_t > & b, Vect< real\_t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.57.4 Member Data Documentation

**LocalVect<real\_t,NEE\_> ePrev** [inherited]

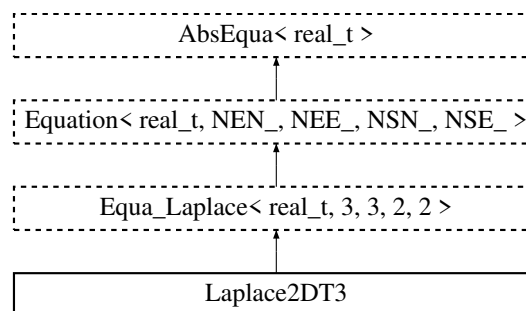
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.58 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 \(\)](#)  
*Default constructor.*
- [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 \(Mesh &ms, Vect< real\\_t > &b, Vect< real\\_t > &Dbc, Vect< real\\_t > &Nbc, Vect< real\\_t > &u\)](#)  
*Constructor that initializes a standard Poisson equation.*
- [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 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.*
- `int run ()`  
*Build and solve the linear system of equations using an iterative method.*
- `void build ()`  
*Build global matrix and right-hand side.*
- `void build (EigenProblemSolver &e)`  
*Build the linear system for an eigenvalue problem.*
- `void updateBC (const Element &el, const Vect< real.t > &bc)`  
*Update Right-Hand side by taking into account essential boundary conditions.*
- `void updateBC (const Vect< real.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< real.t > &b)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< real.t > &b, LocalVect< real.t, NEE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVector (const Vect< real.t > &b, LocalVect< real.t, NEN_ > &be, int dof)`  
*Localize Element Vector from a Vect instance.*
- `void ElementNodeVectorSingleDOF (const Vect< real.t > &b, LocalVect< real.t, NEN_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementSideVector (const Vect< real.t > &b, LocalVect< real.t, NSE_ > &be)`  
*Localize Element Vector from a Vect instance.*
- `void ElementVector (const Vect< real.t > &b, int dof_type=NODE.FIELD, int flag=0)`  
*Localize Element Vector.*
- `void SideVector (const Vect< real.t > &b)`  
*Localize Side Vector.*
- `void ElementNodeCoordinates ()`  
*Localize coordinates of element nodes.*
- `void SideNodeCoordinates ()`  
*Localize coordinates of side nodes.*

- void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)  
*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< [real\\_t](#) > &v)  
*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)  
*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)  
*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([Vect](#)< [real\\_t](#) > &v)  
*Assemble side (edge or face) vector into global one.*
- void [DGElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)  
*Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
- void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)  
*Assemble product of element matrix by element vector into global vector.*
- void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_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< real_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< real_t > & getLinearSolver ()`  
*Return reference to linear solver instance.*
- `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`  
*Choose solver for the linear system.*
- `void setMatrixType (int t)`  
*Choose type of matrix.*
- `int solveLinearSystem (Matrix< real_t > *A, Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< real_t > &b, Vect< real_t > &x)`  
*Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`  
*LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`  
*LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`  
*LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`  
*LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`  
*LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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.*

### 7.58.1 Detailed Description

To build element equation for the Laplace equation using the 2-D triangle element ( $P_1$ ).

To build element equation for the Laplace equation using the 3-D tetrahedral element ( $P_1$ ).

Author

Rachid Touzani

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### 7.58.2 Constructor & Destructor Documentation

**Laplace2DT3 ( Mesh & *ms* )**

Constructor with mesh.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
----	-----------	-------------------------------

**Laplace2DT3 ( 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

**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

**Laplace2DT3 ( Mesh & *ms*, Vect< real.t > & *b*, Vect< real.t > & *D**bc*, Vect< real.t > & *N**bc*, Vect< real.t > & *u* )**

Constructor that initializes a standard Poisson equation.

This constructor sets data for the Poisson equation with mixed (Dirichlet and Neumann) boundary conditions.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in	<i>b</i>	Vector containing the source term (right-hand side of the equation) at mesh nodes
in	<i>Dbc</i>	Vector containing prescribed values of the solution (Dirichlet boundary condition) at nodes with positive code. Its size is the total number of nodes
in	<i>Nbc</i>	Vector containing prescribed fluxes (Neumann boundary conditions) at sides, its size is the total number of sides
in	<i>u</i>	Vector to contain the finite element solution at nodes once the member function <a href="#">run()</a> is called.

### 7.58.3 Member Function Documentation

**void LHS ( *real\_t coef* = 1. )** [virtual]

Add finite element matrix to left-hand side.

Parameters

in	<i>coef</i>	Value to multiply by the added matrix
----	-------------	---------------------------------------

Reimplemented from [Equa.Laplace< real\\_t, 3, 3, 2, 2 >](#).

**void BodyRHS ( const Vect< *real\_t* > &*f* )** [virtual]

Add body source term to right-hand side.

Parameters

in	<i>f</i>	Vector containing the source given function at mesh nodes
----	----------	---

Reimplemented from [Equa.Laplace< real\\_t, 3, 3, 2, 2 >](#).

**void BoundaryRHS ( const Vect< *real\_t* > &*h* )** [virtual]

Add boundary source term to right-hand side.

Parameters

in	<i>h</i>	Vector containing the source given function at mesh nodes
----	----------	---

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	<i>u</i>	Solution at nodes
out	<i>p</i>	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	<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 Axb ( const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**

Compute the product of the stiffness matrix by a given vector.

Parameters

in	<i>x</i>	Vector by which the matrix is multiplied
in	<i>b</i>	Product vector

**int run ( )** [inherited]

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (eps=-1) or the GMRES method if not. The solution is stored in the vector *u* given in the constructor.

Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is 1.e-8

**void build ( )** [inherited]

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.

**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< real.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< real.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< real.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 Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & *b*, LocalVect< real\_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< real\_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< real\_t > & *b* )** [inherited]

Localize Side Vector.

## Parameters

in	<i>b</i>	<p>Global vector to be localized</p> <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> <p>The resulting local vector can be accessed by attribute <code>ePrev</code>.</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< real.t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real.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< real\_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< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real\_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< real\_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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkSMatrix instance
----	-----	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real\_t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > &  $A$  )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The side pointer is given by the global variable theSide

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
-----	--

## Warning

The element pointer is given by the global variable theElement

**void DGElementAssembly ( SkSMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & *A* )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real\_t > & *x*, Vect< real\_t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.



Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

## Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

## Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess of solution on input, actual solution on output

### 7.58.4 Member Data Documentation

**LocalVect<real\_t,NEE\_> ePrev** [inherited]

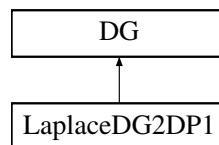
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.59 LaplaceDG2DP1 Class Reference

To build and solve the linear system for the Poisson problem using the [DG](#)  $P_1$  2-D triangle element.

Inheritance diagram for LaplaceDG2DP1:



### Public Member Functions

- [LaplaceDG2DP1](#) ([Mesh](#) &ms, [Vect< real.t >](#) &f, [Vect< real.t >](#) &Dbc, [Vect< real.t >](#) &Nbc, [Vect< real.t >](#) &u)  
*Constructor with mesh and vector data.*
- [~LaplaceDG2DP1](#) ()  
*Destructor.*
- void [set](#) ([real.t](#) sigma, [real.t](#) eps)  
*Set parameters for the [DG](#) method.*
- void [set](#) (const [LocalMatrix< real.t, 2, 2 >](#) &K)  
*Set diffusivity matrix.*
- void [build](#) ()  
*Build global matrix and right-hand side.*
- void [Smooth](#) ([Vect< real.t >](#) &u)  
*Perform post calculations.*
- int [run](#) ()  
*Build and solve the linear system of equations using an iterative method.*
- int [setGraph](#) ()  
*Set matrix graph.*

### 7.59.1 Detailed Description

To build and solve the linear system for the Poisson problem using the [DG](#)  $P_1$  2-D triangle element.

This class build the linear system of equations for a standard elliptic equation using the Discontinuous Galerkin  $P_1$  finite element method.

Author

Rachid Touzani

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### 7.59.2 Constructor & Destructor Documentation

**LaplaceDG2DP1** ( [Mesh](#) & *ms*, `Vect< real.t > & f`, `Vect< real.t > & Dbc`, `Vect< real.t > & Nbc`, `Vect< real.t > & u` )

Constructor with mesh and vector data.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in	<i>f</i>	Vector containing the right-hand side of the elliptic equation at triangle vertices
in	<i>Dbc</i>	Vector containing prescribed values of the solution (Dirichlet boundary condition) at nodes having a positive code
in	<i>Nbc</i>	Vector containing prescribed values of the flux (Neumann boundary condition) at each side having a positive code
in	<i>u</i>	Vector where the solution is stored once the linear system is solved

### 7.59.3 Member Function Documentation

**void set** ( `real.t sigma`, `real.t eps` )

Set parameters for the [DG](#) method.

Parameters

in	<i>sigma</i>	Penalty parameters to enforce continuity at nodes (Must be positive) [Default: 100]
in	<i>eps</i>	<p>Epsilon value of the <a href="#">DG</a> method to choose among the values:</p> <ul style="list-style-type: none"> <li>• 0 Incomplete Interior Penalty Galerkin method (IIPG)</li> <li>• -1 Symmetric Interior Penalty Galerkin method (SIPG)</li> <li>• 1 Non symmetric interior penalty Galerkin method (NIPG)</li> </ul> <p>For a user not familiar with the method, please choose the value of <code>eps=-1</code> and <code>sigma&gt;100</code> which leads to a symmetric positive definite matrix [Default: -1]</p>

**void set ( const LocalMatrix< real\_t, 2, 2 > & K )**

Set diffusivity matrix.

This function provides the diffusivity matrix as instance of class [LocalMatrix](#). The default diffusivity matrix is the identity matrix

Parameters

in	K	Diffusivity matrix
----	---	--------------------

**void build ( )**

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.

**void Smooth ( Vect< real\_t > & u )**

Perform post calculations.

This function gives an averaged solution given at mesh nodes (triangle vertices) by a standard  $L_2$ -projection method.

Parameters

in	u	Solution at nodes
----	---	-------------------

**int run ( )**

Build and solve the linear system of equations using an iterative method.

The matrix is preconditioned by the diagonal ILU method. The linear system is solved either by the Conjugate Gradient method if the matrix is symmetric positive definite (`eps=-1`) or the GMRES method if not. The solution is stored in the vector `u` given in the constructor.

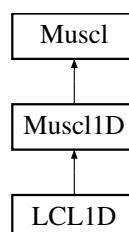
Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is  $1.e-8$

## 7.60 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

## 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.*

### 7.60.1 Detailed Description

Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.

Author

S. Clain, V. Clauzon

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### 7.60.2 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

**7.60.3 Member Function Documentation****void setInitialCondition ( Vect< real\_t > & u )**

Assign initial condition by a vector.

Parameters

in	<i>u</i>	Vector containing initial condition
----	----------	-------------------------------------

**void setInitialCondition ( real\_t u )**

Assign a constant initial condition.

Parameters

in	<i>u</i>	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

in	<i>sd</i>	<a href="#">Side</a> to which value is prescribed
in	<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

in	<i>code</i>	Code of sides to which value is prescribed
in	<i>u</i>	Value to prescribe

**void setVelocity ( Vect< real\_t > & *v* )**

Set convection velocity.

Parameters

in	<i>v</i>	<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.

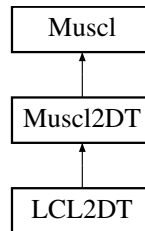
Parameters

in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.61 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

### 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.

### 7.61.1 Detailed Description

Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.

Author

S. Clain, V. Clauzon

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### 7.61.2 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

### 7.61.3 Constructor & Destructor Documentation

**LCL2DT ( Mesh & *m*, Vect< real\_t > & *U* )**

Constructor using mesh and initial data.

Parameters

in	<i>m</i>	Reference to <a href="#">Mesh</a> instance
in	<i>U</i>	Vector containing initial (elementwise) solution

### 7.61.4 Member Function Documentation

**void setInitialCondition ( Vect< real\_t > & u )**

Set elementwise initial condition.

Parameters

in	<i>u</i>	<a href="#">Vect</a> instance containing initial condition values
----	----------	---

**void setInitialCondition ( real\_t u )**

Set a constant initial condition.

Parameters

in	<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

in	<i>sd</i>	<a href="#">Side</a> to which value is prescribed
in	<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

in	<i>code</i>	Code of sides to which value is prescribed
in	<i>u</i>	Value to prescribe

**void setVelocity ( const Vect< real\_t > & v )**

Set convection velocity.

Parameters

in	<i>v</i>	<a href="#">Vect</a> instance containing velocity
----	----------	---

**void setVelocity ( const LocalVect< real\_t, 2 > & v )**

Set (constant) convection velocity.

Parameters

in	<i>v</i>	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	<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], [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	<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

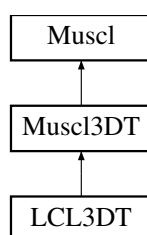
in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.62 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

## 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.

### 7.62.1 Detailed Description

Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.

Author

S. Clain, V. Clauzon

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### 7.62.2 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

### 7.62.3 Constructor & Destructor Documentation

**LCL3DT** ( *Mesh* & *m*, *Vect*< *real.t* > & *U* )

Constructor using mesh and initial field.

Parameters

in	$m$	Reference to <a href="#">Mesh</a> instance
in	$U$	Vector containing initial (elementwise) solution

### 7.62.4 Member Function Documentation

**void setInitialCondition ( Vect< real\_t > &  $u$  )**

Set elementwise initial condition.

Parameters

in	$u$	<a href="#">Vect</a> instance containing initial condition values
----	-----	---

**void setInitialCondition ( real\_t  $u$  )**

Set a constant initial condition.

Parameters

in	$u$	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

in	$sd$	<a href="#">Side</a> to which value is prescribed
in	$u$	Value to prescribe

**void setBC ( int  $code$ , real\_t  $u$  )**

Set Dirichlet boundary condition.  
Assign a constant value sides with a given code

Parameters

in	$code$	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, 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	<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.

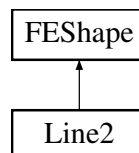
Parameters

in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.63 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.*

### 7.63.1 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.

Author

Rachid Touzani

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### 7.63.2 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
----	-------------	-----------------

### 7.63.3 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	$x$	<a href="#">Point</a> where interpolation is evaluated (in the reference element).
out	$v$	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	$i$	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]

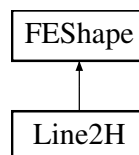
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.64 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.*

### 7.64.1 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.

Author

Rachid Touzani

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### 7.64.2 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 (=> 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>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)
----	----------	--------------------------------------

**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]

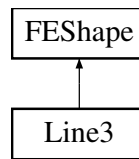
Localize a point in the element.

Return actual coordinates where *s* are coordinates in the reference element.

## 7.65 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.*

### 7.65.1 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.

Author

Rachid Touzani

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### 7.65.2 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	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 Point< real\_t > &s ) const** [inherited]

Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.66 LinearSolver< T\_ > Class Template Reference

Class to solve systems of linear equations by iterative methods.

### Public Member Functions

- [LinearSolver](#) ()  
*Default Constructor.*
- [LinearSolver](#) (int max\_it, [real\\_t](#) tolerance, int verbose)  
*Constructor with iteration parameters.*
- [LinearSolver](#) ([SpMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([SkMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using skyline-stored matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([TrMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using a tridiagonal matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([BMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using a banded matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([DMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using a dense matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([DSMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using a dense symmetric matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([SkSMatrix](#)< T\_ > &A, const [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using skyline-stored symmetric matrix, right-hand side and solution vector.*
- [LinearSolver](#) ([SkMatrix](#)< T\_ > &A, [Vect](#)< T\_ > &b, [Vect](#)< T\_ > &x)  
*Constructor using matrix, right-hand side.*
- virtual [~LinearSolver](#) ()

- Destructor.*
- void **setVerbose** (int verb)  
*Set message level.*
- void **setMaxIter** (int m)  
*Set Maximum number of iterations.*
- void **setTolerance** (real\_t tol)  
*Set tolerance value.*
- void **setSolution** (Vect< T\_ > &x)  
*Set solution vector.*
- void **setRHS** (Vect< T\_ > &b)  
*Set right-hand side vector.*
- void **setMatrix** (OFELI::Matrix< T\_ > \*A)  
*Set matrix in the case of a pointer to Matrix.*
- void **setMatrix** (SpMatrix< T\_ > &A)  
*Set matrix in the case of a pointer to matrix.*
- void **setMatrix** (SkMatrix< T\_ > &A)  
*Set matrix in the case of a skyline matrix.*
- void **set** (SpMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x)  
*Set matrix, right-hand side and initial guess.*
- void **setSolver** (Iteration s, Preconditioner p=DIAG.PREC)  
*Set solver and preconditioner.*
- Iteration **getSolver** () const  
*Return solver code.*
- int **solve** (SpMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x, Iteration s, Preconditioner p=DIAG.PREC)  
*Solve equations using system data, prescribed solver and preconditioner.*
- int **solve** (Iteration s, Preconditioner p=DIAG.PREC)  
*Solve equations using prescribed solver and preconditioner.*
- int **solve** ()  
*Solve equations all arguments must have been given by other member functions.*
- void **setFact** ()  
*Factorize matrix.*
- void **setNoFact** ()  
*Do not factorize matrix.*

### 7.66.1 Detailed Description

```
template<class T_>  
class OFELI::LinearSolver< T_ >
```

Class to solve systems of linear equations by iterative methods.

### 7.66.2 Constructor & Destructor Documentation

**LinearSolver** ( )

Default Constructor.

Initializes default parameters and pointers to 0.

**LinearSolver** ( *int max\_it*, *real\_t tolerance*, *int verbose* )

Constructor with iteration parameters.

## Parameters

in	<i>max_it</i>	Maximal number of iterations
in	<i>tolerance</i>	Tolerance for convergence (measured in relative weighted 2-Norm) in input, effective discrepancy in output.
in	<i>verbose</i>	Information output parameter <ul style="list-style-type: none"> <li>• 0: No output</li> <li>• 1: Output iteration information,</li> <li>• 2 and greater: Output iteration information and solution at each iteration.</li> </ul>

## Author

Rachid Touzani

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**LinearSolver ( SpMatrix< T\_ > & A, const Vect< T\_ > & b, Vect< T\_ > & x )**

Constructor using matrix, right-hand side and solution vector.

## Parameters

in	<i>A</i>	Reference to instance of class <a href="#">SpMatrix</a>
in	<i>b</i>	<a href="#">Vect</a> instance that contains the right-hand side
in,out	<i>x</i>	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( SkMatrix< T\_ > & A, const Vect< T\_ > & b, Vect< T\_ > & x )**

Constructor using skyline-stored matrix, right-hand side and solution vector.

## Parameters

in	<i>A</i>	<a href="#">SkMatrix</a> instance that contains matrix
in	<i>b</i>	<a href="#">Vect</a> instance that contains the right-hand side
in,out	<i>x</i>	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( TrMatrix< T\_ > & A, const Vect< T\_ > & b, Vect< T\_ > & x )**

Constructor using a tridiagonal matrix, right-hand side and solution vector.

## Parameters

in	<i>A</i>	<a href="#">TrMatrix</a> instance that contains matrix
----	----------	--



Parameters

in	$b$	<a href="#">Vect</a> instance that contains the right-hand side
in,out	$x$	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( BMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x )**

Constructor using a banded matrix, right-hand side and solution vector.

Parameters

in	$A$	<a href="#">BMatrix</a> instance that contains matrix
in	$b$	<a href="#">Vect</a> instance that contains the right-hand side
in,out	$x$	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( DMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x )**

Constructor using a dense matrix, right-hand side and solution vector.

Parameters

in	$A$	<a href="#">DMatrix</a> instance that contains matrix
in	$b$	<a href="#">Vect</a> instance that contains the right-hand side
in,out	$x$	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( DSMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x )**

Constructor using a dense symmetric matrix, right-hand side and solution vector.

Parameters

in	$A$	<a href="#">DSMatrix</a> instance that contains matrix
in	$b$	<a href="#">Vect</a> instance that contains the right-hand side
in,out	$x$	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( SkSMatrix< T\_ > &A, const Vect< T\_ > &b, Vect< T\_ > &x )**

Constructor using skyline-stored symmetric matrix, right-hand side and solution vector.

Parameters

in	$A$	<a href="#">SkMatrix</a> instance that contains matrix
in	$b$	<a href="#">Vect</a> instance that contains the right-hand side
in,out	$x$	<a href="#">Vect</a> instance that contains initial guess on input and solution on output

**LinearSolver ( SkMatrix< T\_ > & A, Vect< T\_ > & b, Vect< T\_ > & x )**

Constructor using matrix, right-hand side.

Parameters

in	<i>A</i>	<a href="#">SkMatrix</a> instance that contains matrix
in	<i>b</i>	<a href="#">Vect</a> instance that contains the right-hand side
in,out	<i>x</i>	<a href="#">Vect</a> instance that contains the initial guess on input and solution on output

### 7.66.3 Member Function Documentation

**void setVerbose ( int *verb* )**

Set message level.

Default value is 0

**void setMaxIter ( int *m* )**

Set Maximum number of iterations.

Default value is 1000

**void setMatrix ( OFELI::Matrix< T\_ > \* A )**

Set matrix in the case of a pointer to [Matrix](#).

Parameters

in	<i>A</i>	Pointer to abstract <a href="#">Matrix</a> class
----	----------	--

**void setMatrix ( SpMatrix< T\_ > & A )**

Set matrix in the case of a pointer to matrix.

Parameters

in	<i>A</i>	Pointer to abstract <a href="#">Matrix</a> class
----	----------	--

**void setMatrix ( SkMatrix< T\_ > & A )**

Set matrix in the case of a skyline matrix.

Parameters

in	<i>A</i>	Matrix as instance of class <a href="#">SkMatrix</a>
----	----------	--

**void set ( SpMatrix< T\_ > & A, const Vect< T\_ > & b, Vect< T\_ > & x )**

Set matrix, right-hand side and initial guess.

Parameters

in	$A$	Reference to matrix as a <a href="#">SpMatrix</a> instance
in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess on input and solution on output

**void setSolver ( Iteration  $s$ , Preconditioner  $p$  = DIAG\_PREC )**

Set solver and preconditioner.

Parameters

in	$s$	Solver identification parameter. To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER
in	$p$	Preconditioner identification parameter. By default, the diagonal preconditioner is used. To be chosen in the enumeration variable Preconditioner: IDENT_PREC, DIAG_PREC, SSOR_PREC, ILU_PREC [Default: ILU_PREC]

Note

The argument  $p$  has no effect if the solver is DIRECT\_SOLVER

**int solve ( SpMatrix< T\_ > &  $A$ , const Vect< T\_ > &  $b$ , Vect< T\_ > &  $x$ , Iteration  $s$ , Preconditioner  $p$  = DIAG\_PREC )**

Solve equations using system data, prescribed solver and preconditioner.

Parameters

in	$A$	Reference to matrix as a <a href="#">SpMatrix</a> instance
in	$b$	Vector containing right-hand side
in,out	$x$	Vector containing initial guess on input and solution on output
in	$s$	Solver identification parameter To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER [Default: CGS_SOLVER]
in	$p$	Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner: IDENT_PREC, DIAG_PREC, SSOR_PREC, ILU_PREC, DILU_PREC [Default: DIAG_PREC]

Remarks

The argument  $p$  has no effect if the solver is DIRECT\_SOLVER

Warning

If the library `eigen` is used, only the preconditioners IDENT\_PREC, DIAG\_PREC and ILU\_PREC are available.

**int solve ( Iteration *s*, Preconditioner *p* = DIAG\_PREC )**

Solve equations using prescribed solver and preconditioner.

Parameters

in	<i>s</i>	Solver identification parameter To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER [Default: CGS_SOLVER]
in	<i>p</i>	Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner: IDENT_PREC, DIAG_PREC, SSOR_PREC, DILU_PREC, ILU_PREC [Default: DIAG_PREC]

Note

The argument *p* has no effect if the solver is DIRECT\_SOLVER

**int solve ( )**

Solve equations all arguments must have been given by other member functions.

Solver and preconditioner parameters must have been set by function setSolver. Otherwise, default values are set.

## 7.67 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.*

### 7.67.1 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

$T \leftrightarrow$ -	Data type (double, float, complex<double>, ...)
$N \leftrightarrow$ $R \leftrightarrow$ -	number of rows of matrix
$N \leftrightarrow$ $C \leftrightarrow$ -	number of columns of matrix

## Author

Rachid Touzani

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## 7.67.2 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.

## 7.68 LocalVect&lt; T\_, N\_ &gt; 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 \[Element\]\(#\) &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.*

### 7.68.1 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

T <sub>↔</sub> _↔	Data type (double, float, complex<double>, ...)
N <sub>↔</sub> _↔	Vector size

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### 7.68.2 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>	Reference to <a href="#">Element</a> instance 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>



### 7.68.3 Member Function Documentation

**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]

## 7.69 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 =.*

### 7.69.1 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.

### 7.69.2 Constructor & Destructor Documentation

**Material ( )**

Default constructor.

It initializes the class and searches for the path where are material data files.

### 7.69.3 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.

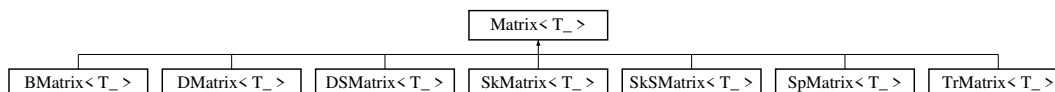
Returns

0 if succeeded, 1 if not.

## 7.70 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.*
- virtual void **reset** ()  
*Set matrix to 0 and reset factorization parameter.*
- 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.*
- virtual void **clear** ()  
*brief Set all matrix entries to zero*
- 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.*
- virtual int **solve** (const **Vect**< T\_ > &b, **Vect**< T\_ > &x)=0  
*Solve the linear system.*
- 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.*

### 7.70.1 Detailed Description

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

Virtual class to handle matrices for all storage formats.

This class enables storing and manipulating dense matrices. The template parameter is the type of matrix entries. Any matrix entry can be accessed by the () operator: For instance, if A is an instance of this class, A(i, j) stands for the entry at the i-th row and j-th column, i and j starting from 1. Entries of A can be assigned a value by the same operator.

Template Parameters

$\langle T_ \leftarrow$	Data type (real_t, float, complex<real_t>, ...)
$\rightarrow$	

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### 7.70.2 Constructor & Destructor Documentation

**Matrix ( )**

Default constructor.

Initializes a zero-size matrix.

### 7.70.3 Member Function Documentation

**virtual void reset ( )** [virtual]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< T\\_ >](#).

**T\_ getDiag ( size\_t k ) const**

Return k-th diagonal entry of matrix.

First entry is given by **getDiag(1)**.

**virtual void Axy ( 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\\_ >](#), [DSMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [Sk←Matrix< 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 `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 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	<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 )**

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 ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =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	<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 ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =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.

If the inherited class is [SpMatrix](#), the function uses an iterative method once this one has been chosen. Otherwise, the method solves the linear system by factorization.

Implemented in [SkSMMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< T\\_ >](#).

**virtual int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [pure virtual]

Solve the linear system.

If the inherited class is [SpMatrix](#), the function uses an iterative method once this one has been chosen. Otherwise, the method solves the linear system by factorization.

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.

Implemented in [SpMatrix< T\\_ >](#), [SkSMMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< T\\_ >](#).

**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	$b$	<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**

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	$i$	Row index
in	$j$	Column index
in	$val$	Value to assign

Implemented in [SpMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DMatrix< 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	$i$	Row index
in	$j$	Column index

Implemented in [SpMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< 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	$i$	Row index
in	$j$	Column index

Implemented in [SpMatrix< T\\_ >](#), [SkSMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< 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

in	<i>i</i>	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.

## 7.71 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, int nb\_dof=1)  
*Constructor using a mesh file.*
- [Mesh](#) (real\_t xmin, real\_t xmax, size\_t nb\_el, size\_t p=1, size\_t nb\_dof=1)  
*Constructor for a 1-D mesh. The domain is the interval [xmin,xmax].*
- [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 xmin, real\_t xmax, size\_t ne, int c1, int c2, int p=1, size\_t nb\_dof=1)  
*Constructor for a uniform 1-D finite element mesh.*
- [Mesh](#) (real\_t xmin, real\_t xmax, real\_t ymin, real\_t ymax, size\_t nx, size\_t ny, int cx0, int cxN, int cy0, int cyN, int opt=0, size\_t nb\_dof=1)  
*Constructor for a uniform 2-D structured finite element mesh.*
- [Mesh](#) (real\_t xmin, real\_t xmax, real\_t ymin, real\_t ymax, real\_t zmin, real\_t zmax, size\_t nx, size\_t ny, size\_t nz, int cx0, int cxN, int cy0, int cyN, int cz0, int czN, int opt=0, size\_t nb\_dof=1)  
*Constructor for a uniform 3-D structured finite element mesh.*
- [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` \* > &nl)  
*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.*
- `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 intrrenal 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.*

### 7.71.1 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](#).

Author

Rachid Touzani

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### 7.71.2 Constructor & Destructor Documentation

**Mesh ( const string &file, bool bc = false, int opt = NODE\_DOF, int nb\_dof = 1 )**

Constructor using a mesh file.

Parameters

in	<i>file</i>	File containing mesh data. The extension of the file yields the file format: The extension .m implies <a href="#">OFELI</a> file format and .msh implies GMSH msh file.
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 NODE_DOF, SIDE_DOF or ELEMENT_DOF. Say if degrees of freedom (unknowns) are supported by nodes, sides or elements.
in	<i>nb_dof</i>	Number of degrees of freedom per node [Default: 1].

**Mesh ( real\_t xmin, real\_t xmax, size\_t nb\_el, size\_t p = 1, size\_t nb\_dof = 1 )**

Constructor for a 1-D mesh. The domain is the interval [xmin,xmax].

Parameters

in	<i>xmin</i>	Value of xmin
in	<i>xmax</i>	Value of xmax
in	<i>nb_el</i>	Number of elements to generate
in	<i>p</i>	Degree of finite element polynomial (Default = 1)

Parameters

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>
in	<i>opt</i>	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 xmin, real.t xmax, size.t ne, int c1, int c2, int p = 1, size.t nb\_dof = 1 )**

Constructor for a uniform 1-D finite element mesh.

The domain is the line (xmin,xmax)

Parameters

in	<i>xmin</i>	Minimal coordinate
in	<i>xmax</i>	Maximal coordinate
in	<i>ne</i>	Number of elements
in	<i>c1</i>	Code for the first node (x=xmin)

## Parameters

in	<i>c2</i>	Code for the last node ( $x=x_{\max}$ )
in	<i>p</i>	Degree of approximation polynomial [Default: 1].
in	<i>nb.dof</i>	Number of degrees of freedom per node [Default: 1].

## Remarks

The option *p* can be set to 1 if the user intends to use finite differences.

**Mesh ( real.t xmin, real.t xmax, real.t ymin, real.t ymax, size.t nx, size.t ny, int cx0, int cxN, int cy0, int cyN, int opt = 0, size.t nb.dof = 1 )**

Constructor for a uniform 2-D structured finite element mesh.

The domain is the rectangle  $(x_{\min}, x_{\max}) \times (y_{\min}, y_{\max})$

## Parameters

in	<i>xmin</i>	Minimal x-coordinate
in	<i>xmax</i>	Maximal x-coordinate
in	<i>ymin</i>	Minimal y-coordinate
in	<i>ymax</i>	Maximal y-coordinate
in	<i>nx</i>	Number of subintervals on the x-axis
in	<i>ny</i>	Number of subintervals on the y-axis
in	<i>cx0</i>	Code for nodes generated on the line $x=x_0$ if $>0$ , for sides on this line if $<0$
in	<i>cxN</i>	Code for nodes generated on the line $x=x_N$ if $>0$ , for sides on this line if $<0$
in	<i>cy0</i>	Code for nodes generated on the line $y=y_0$ if $>0$ , for sides on this line if $<0$
in	<i>cyN</i>	Code for nodes generated on the line $y=y_N$ if $>0$ , for sides on this line if $<0$
in	<i>opt</i>	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.
in	<i>nb.dof</i>	Number of degrees of freedom per node [Default: 1].

## Remarks

The option *opt* can be set to 0 if the user intends to use finite differences.

**Mesh ( real.t xmin, real.t xmax, real.t ymin, real.t ymax, real.t zmin, real.t zmax, size.t nx, size.t ny, size.t nz, int cx0, int cxN, int cy0, int cyN, int cz0, int czN, int opt = 0, size.t nb.dof = 1 )**

Constructor for a uniform 3-D structured finite element mesh.

The domain is the parallelepiped  $(x_{\min}, x_{\max}) \times (y_{\min}, y_{\max}) \times (z_{\min}, z_{\max})$

## Parameters

in	<i>xmin</i>	Minimal x-coordinate
----	-------------	----------------------

## Parameters

in	<i>xmax</i>	Maximal x-coordinate
in	<i>ymin</i>	Minimal y-coordinate
in	<i>ymax</i>	Maximal y-coordinate
in	<i>zmin</i>	Minimal z-coordinate
in	<i>zmax</i>	Maximal z-coordinate
in	<i>nx</i>	Number of subintervals on the x-axis
in	<i>ny</i>	Number of subintervals on the y-axis
in	<i>nz</i>	Number of subintervals on the z-axis
in	<i>cx0</i>	Code for nodes generated on the line x=xmin if >0, for sides on this line if <0
in	<i>cxN</i>	Code for nodes generated on the line x=xmax if >0, for sides on this line if <0
in	<i>cy0</i>	Code for nodes generated on the line y=ymin if >0, for sides on this line if <0
in	<i>cyN</i>	Code for nodes generated on the line y=ymax if >0, for sides on this line if <0
in	<i>cz0</i>	Code for nodes generated on the line z=zmin if >0, for sides on this line if <0
in	<i>czN</i>	Code for nodes generated on the line z=zmax if >0, for sides on this line if <0
in	<i>opt</i>	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: HEXAHEDRON or TETRAHEDRON, with obvious meaning.
in	<i>nb_dof</i>	Number of degrees of freedom per node [Default: 1].

## Remarks

The option *opt* can be set to 0 if the user intends to use finite differences.

**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

in	<i>m</i>	Initial mesh from which the submesh is extracted
in	<i>x</i> ↔ <i>_bl</i>	Coordinate of bottom left vertex of the rectangle
in	<i>x</i> ↔ <i>_tr</i>	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

in	<i>mesh</i>	Initial mesh from which the submesh is extracted
----	-------------	--

Parameters

in	<i>opt</i>	Type of DOF support: To choose among enumerated values <code>NODE_DOF</code> , <code>SIDE_DOF</code> or <code>ELEMENT_DOF</code> .
in	<i>dof1</i>	Label of first degree of freedom to select to the output mesh
in	<i>dof2</i>	Label of last degree of freedom to select to the output mesh
in	<i>bc</i>	Flag to remove (true) or not (false) imposed Degrees of Freedom [Default: false]

**Mesh ( const Mesh & *ms* )**

Copy Constructor.

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance to copy
----	-----------	---------------------------------------

### 7.71.3 Member Function Documentation

**void setDim ( size\_t *dim* )**

Define space dimension. Normally, between 1 and 3.

Parameters

in	<i>dim</i>	Space dimension to set (must be between 1 and 3)
----	------------	--

**void setVerbose ( int *verb* )**

Define Verbose Parameter. Controls output details.

Parameters

in	<i>verb</i>	verbosity parameter (Must be between 0 and 10)
----	-------------	--

**void Add ( Node \* *nd* )**

Add a node to mesh.

Parameters

in	<i>nd</i>	Pointer to <a href="#">Node</a> to add
----	-----------	--

**void Add ( Element \* *el* )**

Add an element to mesh.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> to add
----	-----------	---

**void Add ( Side \* *sd* )**

Add a side to mesh.

Parameters

in	<i>sd</i>	Pointer to <a href="#">Side</a> to add
----	-----------	--

**void Add ( Edge \* *ed* )**

Add an edge to mesh.

Parameters

in	<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
----	------------------	--------------------------------



## Parameters

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

in	<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

in	<i>x</i>	Coordinates of point to define
----	----------	--------------------------------

**size\_t NumberEquations ( size\_t *dof* = 0 )**

Renumber Equations.

Parameters

in	<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* )**

Renumber Equations.

Parameters

in	<i>dof</i>	Label of degree of freedom for which numbering is performed.
in	<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 )**

Renumber 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 <a href="#">OFELI.Config.h</a> )
----	----------	--

**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

in	<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

in	<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

in	<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

in	<i>ed</i>	Pointer to edge to delete
----	-----------	---------------------------

**void RenumberNode ( size\_t *n1*, size\_t *n2* )**

Renumber a node.

Parameters

in	<i>n1</i>	Old label
in	<i>n2</i>	New label

**void RenumberElement ( size\_t *n1*, size\_t *n2* )**

Renumber an element.

Parameters

in	<i>n1</i>	Old label
in	<i>n2</i>	New label

**void RenumberSide ( size\_t *n1*, size\_t *n2* )**

Renumber a side.

Parameters

in	<i>n1</i>	Old label
in	<i>n2</i>	New label

**void RenumberEdge ( size\_t *n1*, size\_t *n2* )**

Renumber an edge.

Parameters

in	<i>n1</i>	Old label
in	<i>n2</i>	New label

**void setNodeView ( size\_t *n1*, size\_t *n2* )**

Set viewing window for nodes.

Parameters

in	<i>n1</i>	First node to view
in	<i>n2</i>	last node to view

**void setElementView ( size\_t *n1*, size\_t *n2* )**

Set viewing window for elements.

Parameters

in	<i>n1</i>	First element to view
in	<i>n2</i>	last element to view

**void setSideView ( size\_t *n1*, size\_t *n2* )**

Set viewing window for sides.

Parameters

in	<i>n1</i>	First side to view
in	<i>n2</i>	last side to view

**void setEdgeView ( size\_t *n1*, size\_t *n2* )**

Set viewing window for edges.

Parameters

in	<i>n1</i>	First edge to view
in	<i>n2</i>	last edge to view

**void setList ( const std::vector< Node \* > & *nl* )**

Initialize list of mesh nodes using the input vector.

Parameters

in	<i>nl</i>	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

in	<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

in	<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

in	<i>sx</i>	Factor to multiply by x coordinates
in	<i>sy</i>	Factor to multiply by y coordinates [Default: <i>sx</i> ]
in	<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

in	<i>g</i>	Option to say of 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

in	<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

in	<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

in	<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 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

in	<i>i</i>	<a href="#">Element</a> index
----	----------	-------------------------------

**size\_t getSideLabel ( size\_t *i* ) const**

Return label of *i*-th side.

Parameters

in	<i>i</i>	<a href="#">Side</a> index
----	----------	----------------------------

**size\_t getEdgeLabel ( size\_t i ) const**

Return label of i-th edge.

Parameters

in	<i>i</i>	Edge 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)

### 7.71.4 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

in	<i>in_mesh</i>	Input mesh
out	<i>out_mesh</i>	Output mesh

## 7.72 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 adaptation process.*
- int [run](#) (const Vect< real\_t > &u)  
*Run adaptation process using a solution vector.*
- int [run](#) (const Vect< real\_t > &u, Vect< real\_t > &v)  
*Run adaptation process using a solution vector and interpolates solution on the adapted mesh.*

### 7.72.1 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

#### Author

Rachid Touzani

#### Copyright

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### 7.72.2 Constructor & Destructor Documentation

#### **MeshAdapt ( Mesh & *ms* )**

Constructor using initial mesh.

Parameters

in	<i>ms</i>	Reference to initial mesh
----	-----------	---------------------------

#### **MeshAdapt ( Domain & *dom* )**

Constructor using a reference to class [Domain](#).

Parameters

in	<i>dom</i>	Reference to <a href="#">Domain</a> class
----	------------	---

### 7.72.3 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

in	<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	<i>u</i>	Vector that contains on output the obtained solutions. This vector is resized before being initialized
in	<i>is</i>	[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	<i>file</i>	File name where the metric is stored
in	<i>u</i>	Solution vector to store

**int run ( )**

Run adaptation process.

Returns

Return code:

- = 0: Adaptation has been normally completed
- = 1: An error occurred

**int run ( const Vect< real\_t > & *u* )**

Run adaptation process using a solution vector.

Parameters

in	$u$	Solution vector defined on the input mesh
----	-----	---

Returns

Return code:

- = 0: Adaptation has been normally completed
- = 1: An error occurred

**int run ( const Vect< real\_t > &  $u$ , Vect< real\_t > &  $v$  )**

Run adaptation process using a solution vector and interpolates solution on the adapted mesh.

Parameters

in	$u$	Solution vector defined on the input mesh
in	$v$	Solution vector defined on the (adapted) output mesh

Returns

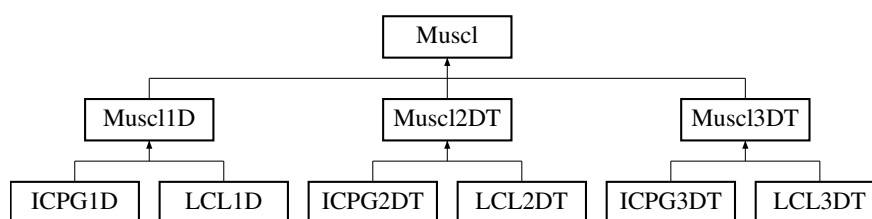
Return code:

- = 0: Adaptation has been normally completed
- = 1: An error occurred

## 7.73 Muscl Class Reference

Parent class for hyperbolic solvers with Muscl scheme.

Inheritance diagram for Muscl:



### Public Types

### 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.*

### 7.73.1 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

Author

S. Clain, V. Clauzon

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### 7.73.2 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

**7.73.3 Member Function Documentation**

**void setTimeStep ( real\_t dt )**

Assign time step value.

Parameters

in	<i>dt</i>	Time step value
----	-----------	-----------------

**void setCFL ( real\_t CFL )**

Assign CFL value.

Parameters

in	<i>CFL</i>	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.

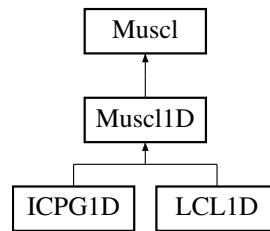
Parameters

in	$l$	Limiter to choose
----	-----	-------------------

## 7.74 Muscl1D Class Reference

Class for 1-D hyperbolic solvers with [Muscl](#) scheme.

Inheritance diagram for Muscl1D:



## Public Types

## 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.*

### 7.74.1 Detailed Description

Class for 1-D hyperbolic solvers with `Muscl` scheme.

Author

S. Clain, V. Clauzon

Copyright

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### 7.74.2 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

### 7.74.3 Member Function Documentation

**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
----	----------	------------------------------

**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.

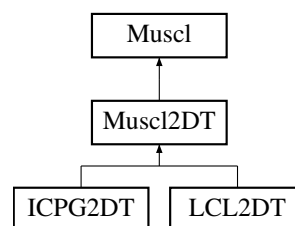
Parameters

in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.75 Muscl2DT Class Reference

Class for 2-D hyperbolic solvers with [Muscl](#) scheme.

Inheritance diagram for Muscl2DT:



### Public Types

### 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.*

### 7.75.1 Detailed Description

Class for 2-D hyperbolic solvers with [Muscl](#) scheme.

Author

S. Clain, V. Clauzon

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### 7.75.2 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

### 7.75.3 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.

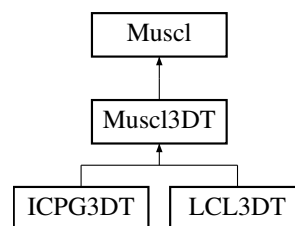
Parameters

in	<i>l</i>	Limiter to choose
----	----------	-------------------

## 7.76 Muscl3DT Class Reference

Class for 3-D hyperbolic solvers with [Muscl](#) scheme using tetrahedra.

Inheritance diagram for Muscl3DT:



### Public Types

### 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.*

### 7.76.1 Detailed Description

Class for 3-D hyperbolic solvers with [Muscl](#) scheme using tetrahedra.

Author

S. Clain, V. Clauzon

Copyright

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### 7.76.2 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

### 7.76.3 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	<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
----	----------	-------------------

## 7.77 MyNLAS Class Reference

Abstract class to define by user specified function.

### Public Member Functions

- [MyNLAS](#) ()  
*Default Constructor.*
- [MyNLAS](#) (const [Mesh](#) &mesh)  
*Constructor using mesh instance.*
- virtual [~MyNLAS](#) ()  
*Destructor.*
- virtual [real\\_t Function](#) (const [Vect](#)< [real\\_t](#) > &x, int i=1)=0  
*Virtual member function to define nonlinear function to zeroe.*
- virtual [real\\_t Gradient](#) (const [Vect](#)< [real\\_t](#) > &x, int i=1, int j=1)  
*Virtual member function to define partial derivatives of function.*

### 7.77.1 Detailed Description

Abstract class to define by user specified function.

The user has to implement a class that inherits from the present one where the virtual functions are implemented.

Author

Rachid Touzani

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### 7.77.2 Constructor & Destructor Documentation

**MyNLAS ( const [Mesh](#) & *mesh* )**

Constructor using mesh instance.

Parameters

<i>mesh</i>	Reference to <a href="#">Mesh</a> instance
-------------	--

### 7.77.3 Member Function Documentation

**virtual [real\\_t Function](#) ( const [Vect](#)< [real\\_t](#) > &*x*, int *i* = 1 )** [pure virtual]

Virtual member function to define nonlinear function to zeroe.

Parameters

in	<i>x</i>	Vector of variables
in	<i>i</i>	component of function to define [Default: 1].

**Returns**

Value of function

**Warning**

The component must not be larger than vector size

**virtual real\_t Gradient ( const Vect< real\_t > &x, int i = 1, int j = 1 )** [virtual]

Virtual member function to define partial derivatives of function.

**Parameters**

in	$x$	Vector of variables
in	$i$	Function component [Default: 1]
in	$j$	Index of partial derivative [Default: 1]

**Returns**

Value of partial derivative

## 7.78 MyOpt Class Reference

Abstract class to define by user specified optimization function.

### Public Member Functions

- [MyOpt \(\)](#)  
*Default Constructor.*
- [MyOpt \(const Mesh &mesh\)](#)  
*Constructor using mesh instance.*
- [virtual ~MyOpt \(\)](#)  
*Destructor.*
- [virtual real\\_t Objective \(const Vect< real\\_t > &x\)=0](#)  
*Virtual member function to define objective.*
- [virtual void Gradient \(const Vect< real\\_t > &x, Vect< real\\_t > &g\)](#)  
*Virtual member function to define gradient vector of objective.*

### 7.78.1 Detailed Description

Abstract class to define by user specified optimization function.

The user has to implement a class that inherits from the present one where the virtual functions are implemented.

**Author**

Rachid Touzani

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### 7.78.2 Constructor & Destructor Documentation

**MyOpt** ( **const Mesh** & *mesh* )

Constructor using mesh instance.

Parameters

<i>mesh</i>	Reference to <a href="#">Mesh</a> instance
-------------	--

### 7.78.3 Member Function Documentation

**virtual real\_t Objective** ( **const Vect< real\_t >** & *x* ) [pure virtual]

Virtual member function to define objective.

Parameters

in	<i>x</i>	Vector of optimization variables
----	----------	----------------------------------

Returns

Value of objective

**virtual void Gradient** ( **const Vect< real\_t >** & *x*, **Vect< real\_t >** & *g* ) [virtual]

Virtual member function to define gradient vector of objective.

Parameters

in	<i>x</i>	Vector of optimization variables
out	<i>g</i>	Gradient vector

## 7.79 NLASSolver Class Reference

To solve a system of nonlinear algebraic equations of the form  $f(u) = 0$ .

### Public Member Functions

- [NLASSolver](#) ()  
*Default constructor.*
- [NLASSolver](#) (NonLinearIter nl, int nb\_eq=1)  
*Constructor defining the iterative method to solve the equation.*
- [NLASSolver](#) (real\_t &x, NonLinearIter nl=NEWTON)  
*Constructor defining a one-variable problem.*
- [NLASSolver](#) (Vect< real\_t > &x, NonLinearIter nl=NEWTON)  
*Constructor defining a multi-variable problem.*
- [NLASSolver](#) (MyNLAS &my\_nlas, NonLinearIter nl=NEWTON)

Constructor using a user defined class.

- `~NLASSolver ()`

Destructor.

- `void setVerbose (int verb)`

Set verbosity parameter Value must be between 0 and 5. Default value is 0.

- `void setMaxIter (int max_it)`

Set Maximal number of iterations.

- `void setTolerance (real_t toler)`

Set tolerance value for convergence.

- `void set (NonLinearIter nl)`

Define an iterative procedure To be chosen among the enumerated values: `BISECTION`, `REGULA_FALSI` or `NEWTON`.

- `void setFunction (function< real_t(real_t)> f)`

Define the function associated to the equation to solve.

- `void setFunction (function< Vect< real_t >(Vect< real_t >)> f)`

Define the function associated to the equation to solve.

- `void setGradient (function< real_t(real_t)> g)`

Define the function associated to the derivative of the equation to solve.

- `void setGradient (function< Vect< real_t >(Vect< real_t >)> g)`

Define the function associated to the gradient of the equation to solve.

- `void setf (string exp)`

Set function for which zero is sought (case of one equation)

- `void setDf (string exp, int i=1, int j=1)`

Set pztial derivative of function for which zero is sought (case of many equations)

- `void setPDE (AbsEqua< real_t > &eq)`

Define a PDE.

- `void setInitial (Vect< real_t > &u)`

Set initial guess for the iterations.

- `void setInitial (real_t &x)`

Set initial guess for a unique unknown.

- `void setInitial (real_t a, real_t b)`

Set initial guesses bisection or Regula falsi algorithms.

- `void run ()`

Run the solution procedure.

- `real_t get () const`

Return solution (Case of a scalar equation)

- `void get (Vect< real_t > &u) const`

Return solution (case of a nonlinear system of equations)

- `int getNbIter () const`

Return number of iterations.

### 7.79.1 Detailed Description

To solve a system of nonlinear algebraic equations of the form  $f(u) = 0$ .

Features:

- The nonlinear problem is solved by the Newton's method in the general case, and in the one variable case, either by the bisection or the Regula Falsi method
- The function and its gradient are given:
  - Either by regular expressions
  - Or by user defined functions
  - Or by a user defined class. This feature enables defining the function and its gradient through a PDE class for instance

### 7.79.2 Constructor & Destructor Documentation

**NLASSolver ( NonLinearIter *nl*, int *nb\_eq* = 1 )**

Constructor defining the iterative method to solve the equation.

Parameters

in	<i>nl</i>	Choose an iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: BISECTION, REGULA_FALSI or NEWTON.
in	<i>nb<sub>eq</sub></i>	Number of equations [Default: 1]

**NLASSolver ( real\_t & *x*, NonLinearIter *nl* = NEWTON )**

Constructor defining a one-variable problem.

Parameters

in	<i>x</i>	Variable containing on input initial guess and on output solution, if convergence is achieved
in	<i>nl</i>	Iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: BISECTION, REGULA_FALSI or NEWTON.

**NLASSolver ( Vect< real\_t > & *x*, NonLinearIter *nl* = NEWTON )**

Constructor defining a multi-variable problem.

Parameters

in	<i>x</i>	Variable containing on input initial guess and on output solution, if convergence is achieved
in	<i>nl</i>	Iterative procedure to solve the nonlinear system of equations: The only possible value (default one) in the current version is NEWTON.

**NLASSolver ( MyNLAS & *my\_nlas*, NonLinearIter *nl* = *NEWTON* )**

Constructor using a user defined class.

Parameters

in	<i>my_nlas</i>	Reference to instance of user defined class. This class inherits from abstract class <a href="#">MyNLAS</a> . It must contain the member function <code>Vect&lt;double&gt; Function(const Vect&lt;double&gt;&amp; x)</code> which returns the value of the nonlinear function, as a vector, for a given solution vector <i>x</i> . The user defined class must contain, if the iterative scheme requires it the member function <code>Vect&lt;double&gt; Gradient(const Vect&lt;real.t&gt;&amp; x)</code> which returns the gradient as a <i>n</i> * <i>n</i> vector, each index ( <i>i,j</i> ) containing the <i>j</i> -th partial derivative of the <i>i</i> -th function.
in	<i>nl</i>	Iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: <code>BISECTION</code> , <code>REGULA_FALSI</code> or <code>NEWTON</code> .

### 7.79.3 Member Function Documentation

**void setMaxIter ( int *max\_it* )**

Set Maximal number of iterations.

Default value of this parameter is 100

**void setTolerance ( real.t *toler* )**

Set tolerance value for convergence.

Default value of this parameter is 1.e-8

**void setFunction ( function< real.t(real.t)> *f* )**

Define the function associated to the equation to solve.

This function can be used in the case where a user defined function is to be given. To be used in the one-variable case.

Parameters

in	<i>f</i>	Function given as a function of one real variable and returning a real number. This function can be defined by the calling program as a C-function and then cast to an instance of class function
----	----------	---

**void setFunction ( function< Vect< real.t >(Vect< real.t >)> *f* )**

Define the function associated to the equation to solve.

This function can be used in the case where a user defined function is to be given.

Parameters

in	<i>f</i>	Function given as a function of many variables, stored in an input vector, and returns a vector. This function can be defined by the calling program as a C-function and then cast to an instance of class function
----	----------	---

**void setGradient ( function< real\_t(real\_t)> g )**

Define the function associated to the derivative of the equation to solve.

Parameters

in	<i>g</i>	Function given as a function of one real variable and returning a real number. This function can be defined by the calling program as a C-function and then cast to an instance of class function
----	----------	---

**void setGradient ( function< Vect< real\_t >(Vect< real\_t >)> g )**

Define the function associated to the gradient of the equation to solve.

Parameters

in	<i>g</i>	Function given as a function of many variables, stored in an input vector. and returns a $n \times n$ vector ( $n$ is the number of variables). This function can be defined by the calling program as a C-function and then cast to an instance of class function
----	----------	--

**void setf ( string *exp* )**

Set function for which zero is sought (case of one equation)

Parameters

in	<i>exp</i>	Regular expression defining the function using the symbol $x$ as a variable
----	------------	---

**void setDf ( string *exp*, int *i* = 1, int *j* = 1 )**

Set partial derivative of function for which zero is sought (case of many equations)

Parameters

in	<i>exp</i>	Regular expression defining the partial derivative. In this expression, the variables are $x_1, x_2, \dots, x_{10}$ (up to 10 variables)
in	<i>i</i>	Component of function [Default: =1]
in	<i>j</i>	Index of the partial derivative [Default: =1]

**void setPDE ( AbsEqua< real\_t > & *eq* )**

Define a PDE.

The solver can be used to solve a nonlinear PDE. In this case, the PDE is defined as an instance of a class inheriting of [AbsEqua](#).

## Parameters

## Parameters

in	<i>eq</i>	Pointer to equation instance
----	-----------	------------------------------

**void setInitial ( Vect< real\_t > & *u* )**

Set initial guess for the iterations.

## Parameters

in	<i>u</i>	Vector containing initial guess for the unknown
----	----------	---

**void setInitial ( real\_t & *x* )**

Set initial guess for a unique unknown.

## Parameters

in	<i>x</i>	Rference to value of initial guess
----	----------	------------------------------------

**void setInitial ( real\_t *a*, real\_t *b* )**

Set initial guesses bisection or Regula falsi algorithms.

## Parameters

in	<i>a</i>	Value of first initial guess
in	<i>b</i>	Value of second initial guess

## Note

The function has to have opposite signs at these values i.e.  $f(a)f(b) < 0$ .

## Warning

This function makes sense only in the case of a unique function of one variable

**void get ( Vect< real\_t > & *u* ) const**

Return solution (case of a nonlinear system of equations)

## Parameters

out	<i>u</i>	Vector that contains on output the solution
-----	----------	---

## 7.80 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.*

### 7.80.1 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 `getNode↔NeighborElements` 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.

### 7.80.2 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

in	<i>label</i>	Label of node
in	<i>x</i>	Node coordinates



### 7.80.3 Member Function Documentation

**void setCode ( size\_t *dof*, int *code* )**

Define code for a given DOF of node.

Parameters

in	<i>dof</i>	DOF index
in	<i>code</i>	Code to assign to DOF

**void setCode ( const vector< int > &*code* )**

Define codes for all node DOFs.

Parameters

in	<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

in	<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

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
in	<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

in	<i>i</i>	Coordinate index (1..3)
in	<i>x</i>	Coordinate value

**void DOF ( size\_t *i*, size\_t *dof* )**

Define label of DOF.

Parameters

in	<i>i</i>	DOF index
in	<i>dof</i>	Label of DOF

**void setDOF ( size\_t &*first\_dof*, size\_t *nb\_dof* )**

Define number of DOF.

Parameters

in,out	<i>first_dof</i>	Label of the first DOF in input that is actualized
in	<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

in	<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 `getNode↵NeighborElements()` 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

**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

## 7.81 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)*

### 7.81.1 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.

Author

Rachid Touzani

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### 7.81.2 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

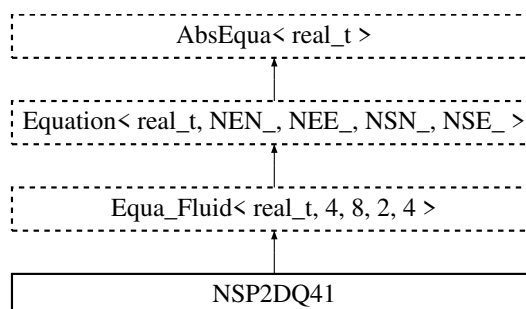
in	<i>x</i>	x-coordinate that share the selected nodes
in	<i>y</i>	y-coordinate that share the selected nodes [Default: ANY]
in	<i>z</i>	z-coordinate that share the selected nodes [Default: ANY]

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)`;

## 7.82 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](#)< [real\\_t](#) > &bc)
- Update Right-Hand side by taking into account essential boundary conditions.*

  - void [updateBC](#) (const [Vect](#)< [real\\_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](#)< [real\\_t](#) > &b)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEE\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be, int dof)
- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NEN\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), NSE\_ > &be)
- Localize Element Vector from a Vect instance.*

  - void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)
- Localize Element Vector.*

  - void [SideVector](#) (const [Vect](#)< [real\\_t](#) > &b)
- Localize Side Vector.*

  - void [ElementNodeCoordinates](#) ()
- Localize coordinates of element nodes.*

  - void [SideNodeCoordinates](#) ()
- Localize coordinates of side nodes.*

  - void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)
- Assemble element right-hand side vector into global one.*

  - void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)

- Assemble element matrix into global one.*
  - void [ElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one.*
  - void [ElementAssembly](#) ([Vect](#)< [real\\_t](#) > &v)
- Assemble element vector into global one.*
  - void [SideAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)
- Assemble side matrix into global one.*
  - void [SideAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)
- Assemble side right-hand side vector into global one.*
  - void [SideAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)
- Assemble side (edge or face) matrix into global one.*
  - void [SideAssembly](#) ([Vect](#)< [real\\_t](#) > &v)
- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_t](#) > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real\\_t](#) > &x, [Vect](#)< [real\\_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](#)< [real\\_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< real_t > & getLinearSolver ()`
- Return reference to linear solver instance.*
- `void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)`
- Choose solver for the linear system.*
- `void setMatrixType (int t)`
- Choose type of matrix.*
- `int solveLinearSystem (Matrix< real_t > *A, Vect< real_t > &b, Vect< real_t > &x)`
- Solve the linear system with given matrix and right-hand side.*
- `int solveLinearSystem (Vect< real_t > &b, Vect< real_t > &x)`
- Solve the linear system with given right-hand side.*

## Public Attributes

- `LocalMatrix< real_t, NEE_, NEE_ > eMat`
- LocalMatrix instance containing local matrix associated to current element.*
- `LocalMatrix< real_t, NSE_, NSE_ > sMat`
- LocalMatrix instance containing local matrix associated to current side.*
- `LocalVect< real_t, NEE_ > ePrev`
- LocalVect instance containing local vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRHS`
- LocalVect instance containing local right-hand side vector associated to current element.*
- `LocalVect< real_t, NEE_ > eRes`
- LocalVect instance containing local residual vector associated to current element.*
- `LocalVect< real_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.*



### 7.82.1 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.

Author

Rachid Touzani

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### 7.82.2 Constructor & Destructor Documentation

**NSP2DQ41 ( )**

Default Constructor.

Builds an empty equation

**NSP2DQ41 ( const Element \* *el* )**

Constructor using [Element](#) data.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
----	-----------	---

**NSP2DQ41 ( const Side \* *sd* )**

Constructor using [Side](#) data.

Parameters

in	<i>sd</i>	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

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
in	<i>u</i>	Vector that contains velocity at previous time step
in	<i>time</i>	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

in	<i>sd</i>	Pointer to <a href="#">Side</a> instance
in	<i>u</i>	Vector that contains velocity at previous time step
in	<i>time</i>	Time value [Default: 0.]

### 7.82.3 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

in	<i>ud</i>	<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

in	<i>ud</i>	<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

in	<i>coef</i>	Value of penalty parameter [Default: 1.e20].
----	-------------	--

**void updateBC ( const Element & el, const Vect< real\_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< real.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>• <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>dof</i>	DOF setting: <ul style="list-style-type: none"> <li>• <i>= 0</i>, All DOFs are taken into account [Default]</li> <li>• <i>!= 0</i>, Only DOF No. <i>dof</i> is handled in the system</li> </ul>

**void LocalNodeVector ( Vect< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_t, NSE\_ > & be )**  
[inherited]

Localize Element Vector from a Vect instance.

Parameters

in	<i>b</i>	Global vector to be localized.
----	----------	--------------------------------

## Parameters

out	<i>be</i>	Local vector, the length of which is
-----	-----------	--------------------------------------

**void ElementVector ( const Vect< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>A</code>	Global matrix stored as a BMatrix instance
----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real.t > & A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real.t > & b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--



## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkSMatrix instance
----	---	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

## 7.82.4 Member Data Documentation

**LocalVect<real.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

## 7.83 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 `setDF` (string df)  
*Set derivative with respect to the unknown of the function defining the 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-order ODEs.*
- void `seODEVectors` (`Vect`< `real.t` > &a0, `Vect`< `real.t` > &a1)  
*Define matrices for an implicit nonlinear system of first-order ODEs.*
- void `seODEVectors` (`Vect`< `real.t` > &a0, `Vect`< `real.t` > &a1, `Vect`< `real.t` > &a2)  
*Define matrices for an implicit nonlinear system of second-order 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:*  
 • void `setMaxIter (int max_it)`
- *Set maximal number of iterations.*  
 • void `setTolerance (real_t toler)`
- *Set tolerance value for convergence.*  
 • `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 getTimeDerivative (int i=1) const`
- *Get time derivative of solution.*  
 • void `getTimeDerivative (Vect< real_t > &y) const`
- *Get time derivative of solution (for a system)*  
 • `real_t get () const`
- *Return solution in the case of a scalar equation.*

### 7.83.1 Detailed Description

To solve a system of ordinary differential equations.

The class `ODESolver` enables solving by a numerical scheme a system or ordinary differential equations taking one of the forms:

- A linear system of differential equations of the first-order:  

$$\mathbf{A}_1(\mathbf{t})\mathbf{u}'(\mathbf{t}) + \mathbf{A}_0(\mathbf{t})\mathbf{u}(\mathbf{t}) = \mathbf{f}(\mathbf{t})$$
- A linear system of differential equations of the second-order:  

$$\mathbf{A}_2(\mathbf{t})\mathbf{u}''(\mathbf{t}) + \mathbf{A}_1(\mathbf{t})\mathbf{u}'(\mathbf{t}) + \mathbf{A}_0(\mathbf{t})\mathbf{u}(\mathbf{t}) = \mathbf{f}(\mathbf{t})$$
- A system of ordinary differential equations of the form:  

$$\mathbf{u}'(\mathbf{t}) = \mathbf{f}(\mathbf{t}, \mathbf{u}(\mathbf{t}))$$

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

Author

Rachid Touzani

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### 7.83.2 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 if the value given by the global variable theTimeStep
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 theFinalTime
in	<i>nb_eq</i>	Number of differential equations (size of the system) [Default: 1]

### 7.83.3 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 if the value given by the global variable theTimeStep
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 theFinalTime

**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	$a0$	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 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 if 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 setDF ( string  $df$  )**

Set derivative with respect to the unknown of the function defining the 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
in	$v$	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

in	$f$	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

in	$u$	Initial condition (unknown) value
in	$v$	Initial condition (time derivative of the unknown) value

**void setInitial ( real\_t  $u$  )**

Set initial condition for a first-order ordinary differential equation.

Parameters

in	$u$	Initial condition (unknown) value
----	-----	-----------------------------------

**void setInitialRHS ( real\_t  $f$  )**

Set initial right-hand side for a single differential equation.

Parameters

in	$f$	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

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)

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-order 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 seODEVectors ( Vect< real\_t > & a0, Vect< real\_t > & a1 )**

Define matrices for an implicit nonlinear system of first-order ODEs.

The system has the nonlinear implicit form  $a1(u)' + a0(u) = 0$  Vectors a0, a1 are given as references to class [Vect](#).

## Parameters

in	<i>a0</i>	Reference to vector in front of the 0-th order term (no time derivative)
in	<i>a1</i>	Reference to vector in front of the 1-st order term (first time derivative)

## Remarks

This function has to be called at each time step

**void seODEVectors ( Vect< real\_t > & a0, Vect< real\_t > & a1, Vect< real\_t > & a2 )**

Define matrices for an implicit nonlinear system of second-order ODEs.

The system has the nonlinear implicit form  $a2(u)'' + a1(u)' + a0(u) = 0$  Vectors a0, a1, a2 are given as references to class [Vect](#).

## Parameters

in	<i>a0</i>	Reference to vector in front of the 0-th order term (no time derivative)
in	<i>a1</i>	Reference to vector in front of the 1-st order term (first time derivative)
in	<i>a2</i>	Reference to vector 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	<i>b</i>	<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	<i>beta</i>	Parameter beta [Default: 0.25]
in	<i>gamma</i>	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	<i>s</i>	Solver identification parameter. To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER [Default: DIRECT_SOLVER]
in	<i>p</i>	Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner: 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

**void setMaxIter ( int *max\_it* )**

Set maximal number of iterations.

This function is useful for a non linear ODE (or system of ODEs) if an implicit scheme is used

Parameters

in	<i>max</i> ↔ <i>_it</i>	Maximal number of iterations [Default: 100]
----	----------------------------	---

**void setTolerance ( real\_t *toler* )**

Set tolerance value for convergence.

This function is useful for a non linear ODE (or system of ODEs) if an implicit scheme is used

Parameters

in	<i>toler</i>	Tolerance value [Default: 1.e-8]
----	--------------	----------------------------------

**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

**real\_t getTimeDerivative ( int *i* = 1 ) const**

Get time derivative of solution.

Return approximate time derivative of solution in the case of a single equation

Parameters

in	<i>i</i>	Index of component whose time derivative is sought
----	----------	--

**Returns**

Time derivative of the i-th component of the solution

**Remarks**

If we are solving one equation, this parameter is not used.

**void getTimeDerivative ( Vect< real\_t > & y ) const**

Get time derivative of solution (for a system)

Get approximate time derivative of solution in the case of an ODE system

**Parameters**

out	y	Vector containing time derivative of solution
-----	---	---

## 7.84 OFELIException Class Reference

To handle exceptions in [OFELI](#).

Inherits runtime\_error.

**Public Member Functions**

- [OFELIException](#) (const std::string &s)

*This form will be used most often in a throw.*

- [OFELIException](#) ()

*Throw with no error message.*

### 7.84.1 Detailed Description

To handle exceptions in [OFELI](#).

This class enables using exceptions in programs using [OFELI](#)

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Rachid Touzani

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## 7.85 OptSolver Class Reference

To solve an optimization problem with bound constraints.

## Public Types

## Public Member Functions

- `OptSolver ()`  
*Default constructor.*
- `OptSolver (Vect< real_t > &x)`  
*Constructor using vector of optimization variables.*
- `OptSolver (MyOpt &opt, Vect< real_t > &x)`  
*Constructor using vector of optimization variables.*
- `~OptSolver ()`  
*Destructor.*
- `int getNbFctEval () const`  
*Return the total number of function evaluations.*
- `void setOptMethod (OptMethod m)`  
*Choose optimization method.*
- `void setBC (const Vect< real_t > &bc)`  
*Prescribe boundary conditions as constraints.*
- `void setObjective (string exp)`  
*Define the objective function to minimize by an algebraic expression.*
- `void setGradient (string exp, int i=1)`  
*Define a component of the gradient of the objective function to minimize by an algebraic expression.*
- `void setOptClass (MyOpt &opt)`  
*Choose user defined optimization class.*
- `void setUpperBound (real_t ub)`  
*Define upper bound for optimization variable.*
- `void setUpperBounds (Vect< real_t > &ub)`  
*Define upper bounds for optimization variables.*
- `void setLowerBound (real_t lb)`  
*Define lower bound for optimization variable.*
- `void setVerbosity (int verb)`  
*Set verbosity parameter.*
- `void setLowerBounds (Vect< real_t > &lb)`  
*Define lower bounds for optimization variables.*
- `void setSAOpt (real_t rt, int ns, int nt, int &neps, int maxevl, real_t t, Vect< real_t > &vm, Vect< real_t > &xopt, real_t &fopt)`  
*Set Simulated annealing options.*
- `void setTolerance (real_t toler)`  
*Set error tolerance.*
- `void setMaxIterations (int n)`  
*Set maximal number of iterations.*
- `int getNbObjEval () const`  
*Return number of objective function evaluations.*
- `real_t getTemperature () const`  
*Return the final temperature.*
- `int getNbAcc () const`  
*Return the number of accepted objective function evaluations.*
- `int getNbOutOfBounds () const`



*Return the total number of trial function evaluations that would have been out of bounds.*

- `real_t getOptObj () const`

*Return Optimal value of the objective.*

- `int run ()`

*Run the optimization algorithm.*

- `int run (real_t toler, int max_it, int verb)`

*Run the optimization algorithm.*

- `real_t getSolution () const`

*Return solution in the case of a one variable optimization.*

- `void getSolution (Vect< real_t > &x) const`

*Get solution vector.*

## Friends

- `ostream & operator<< (ostream &s, const OptSolver &os)`

*Output class information.*

## 7.85.1 Detailed Description

To solve an optimization problem with bound constraints.

Author

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## 7.85.2 Member Enumeration Documentation

### enum OptMethod

Choose optimization algorithm.

Enumerator

**GRADIENT** Gradient method

**TRUNCATED\_NEWTON** Truncated Newton method

**SIMULATED\_ANNEALING** Simulated annealing global optimization method

**NELDER\_MEAD** Nelder-Mead global optimization method

## 7.85.3 Constructor & Destructor Documentation

### OptSolver ( Vect< real\_t > &x )

Constructor using vector of optimization variables.

Parameters

in	$x$	Vector having as size the number of optimization variables. It contains the initial guess for the optimization algorithm.
----	-----	---

## Remarks

After using the member function `run`, the vector  $x$  contains the obtained solution if the optimization procedure was successful

**OptSolver ( MyOpt & *opt*, Vect< real.t > & *x* )**

Constructor using vector of optimization variables.

## Parameters

in	<i>opt</i>	Reference to instance of user defined optimization class. This class inherits from abstract class <a href="#">MyOpt</a> . It must contain the member function <code>double Objective(const Vect&lt;double&gt; &amp;x)</code> which returns the value of the objective for a given solution vector $x$ . The user defined class must contain, if the optimization algorithm requires it the member function <code>Gradient(const Vect&lt;double&gt; &amp;x, Vect&lt;double&gt; &amp;g)</code> which stores the gradient of the objective in the vector $g$ for a given optimization vector $x$ . The user defined class must also contain, if the optimization algorithm requires it the member function
in	$x$	Vector having as size the number of optimization variables. It contains the initial guess for the optimization algorithm.

## Remarks

After using the member function `run`, the vector  $x$  contains the obtained solution if the optimization procedure was successful

### 7.85.4 Member Function Documentation

**void setOptMethod ( OptMethod *m* )**

Choose optimization method.

## Parameters

in	<i>m</i>	<p>Enumerated value to choose the optimization algorithm to use. Must be chosen among the enumerated values:</p> <ul style="list-style-type: none"> <li>• GRADIENT: Gradient steepest descent method with projection for bounded constrained problems</li> <li>• TRUNCATED_NEWTON: The Nash's Truncated Newton Algorithm, due to S.G. Nash (Newton-type Minimization via the Lanczos method, SIAM J. Numer. Anal. 21 (1984) 770-778).</li> <li>• SIMULATED_ANNEALING: Global optimization simulated annealing method. See 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.</li> <li>• NELDER_MEAD: Global optimization Nelder-Mead method due to John Nelder, Roger Mead (A simplex method for function minimization, Computer Journal, Volume 7, 1965, pages 308-313). As implemented by R. O'Neill (Algorithm AS 47: Function Minimization Using a Simplex Procedure, Applied Statistics, Volume 20, Number 3, 1971, pages 338-345).</li> </ul>
----	----------	--

**void setBC ( const Vect< real\_t > & bc )**

Prescribe boundary conditions as constraints.

This member function is useful in the case of optimization problems where the optimization variable vector is the solution of a partial differential equation. For this case, Dirichlet boundary conditions can be prescribed as constraints for the optimization problem

## Parameters

in	<i>bc</i>	Vector containing the values to impose on degrees of freedom. This vector must have been constructed using the <a href="#">Mesh</a> instance.
----	-----------	---

## Remarks

Only degrees of freedom with positive code are taken into account as prescribed

**void setObjective ( string exp )**

Define the objective function to minimize by an algebraic expression.

## Parameters

in	<i>exp</i>	Regular expression defining the objective function
----	------------	--

**void setGradient ( string *exp*, int *i* = 1 )**

Define a component of the gradient of the objective function to minimize by an algebraic expression.

Parameters

in	<i>exp</i>	Regular expression defining the objective function
in	<i>i</i>	Component of gradient [Default: 1]

**void setOptClass ( MyOpt & *opt* )**

Choose user defined optimization class.

Parameters

in	<i>opt</i>	Reference to inherited user specified optimization class
----	------------	--

**void setUpperBound ( real\_t *ub* )**

Define upper bound for optimization variable.  
Case of a one-variable problem

Parameters

in	<i>ub</i>	Upper bound
----	-----------	-------------

**void setUpperBounds ( Vect< real\_t > & *ub* )**

Define upper bounds for optimization variables.

Parameters

in	<i>ub</i>	Vector containing upper values for variables
----	-----------	--

**void setLowerBound ( real\_t *lb* )**

Define lower bound for optimization variable.  
Case of a one-variable problem

Parameters

in	<i>lb</i>	Lower value
----	-----------	-------------

**void setVerbosity ( int *verb* )**

Set verbosity parameter.

## Parameters

in	<i>verb</i>	Verbosity parameter
----	-------------	---------------------

**void setLowerBounds ( Vect< real.t > & lb )**

Define lower bounds for optimization variables.

## Parameters

in	<i>lb</i>	Vector containing lower values for variables
----	-----------	--

**void setSAOpt ( real.t *rt*, int *ns*, int *nt*, int & *neps*, int *maxevl*, real.t *t*, Vect< real.t > & *vm*, Vect< real.t > & *xopt*, real.t & *fopt* )**

Set Simulated annealing options.

## Remarks

This member function is useful only if simulated annealing is used.

## Parameters

in	<i>rt</i>	The temperature reduction factor. The value suggested by Corana et al. is .85. See Goffe et al. for more advice.
	<i>maxevl</i>	[in] The maximum number of function evaluations. If it is exceeded, the return <i>code</i> =1.
in	<i>ns</i>	Number of cycles. After <i>ns*nb_var</i> function evaluations, each element of <i>vm</i> is adjusted so that approximately half of all function evaluations are accepted. The suggested value is 20.
in	<i>nt</i>	Number of iterations before temperature reduction. After <i>nt*ns*n</i> function evaluations, temperature ( <i>t</i> ) is changed by the factor <i>rt</i> . Value suggested by Corana et al. is <i>max(100,5*nb_var)</i> . 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
in	<i>maxevl</i>	
in	<i>t</i>	The initial temperature. See Goffe et al. for advice.
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> , the next trial point is selected is from <i>x[i]-vm[i]</i> to <i>x[i]+vm[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).
in	<i>xopt</i>	
in	<i>fopt</i>	

**void setTolerance ( real\_t toler )**

Set error tolerance.

Parameters

in	<i>toler</i>	Error tolerance for termination. If the final function values from the last neps 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 toler, execution terminates and the value 0 is returned.
----	--------------	---

**real\_t getTemperature ( ) const**

Return the final temperature.

This function is meaningful only if the Simulated Annealing algorithm is used

**int getNbAcc ( ) const**

Return the number of accepted objective function evaluations.

This function is meaningful only if the Simulated Annealing algorithm is used

**int getNbOutOfBounds ( ) const**

Return the total number of trial function evaluations that would have been out of bounds.

This function is meaningful only if the Simulated Annealing algorithm is used

**int run ( )**

Run the optimization algorithm.

This function runs the optimization procedure using default values for parameters. To modify these values, use the function run with arguments

**int run ( real\_t toler, int max\_it, int verb )**

Run the optimization algorithm.

Parameters

in	<i>toler</i>	Tolerance value for convergence testing
in	<i>max_it</i>	Maximal number of iterations to achieve convergence
in	<i>verb</i>	Verbosity parameter (to choose between 0 and 10)

**real\_t getSolution ( ) const**

Return solution in the case of a one variable optimization.

In the case of a one variable problem, the solution value is returned, if the optimization procedure was successful

**void getSolution ( Vect< real\_t > & x ) const**

Get solution vector.

The vector  $x$  contains the solution of the optimization problem. Note that if the constructor using an initial vector was used, the vector will contain the solution once the member function run has been used (If the optimization procedure was successful)

Parameters

out	$x$	solution vector
-----	-----	-----------------

## 7.86 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 \(Mesh &mesh, int n, vector< int > &repart, int verb=0\)](#)  
*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.*

### 7.86.1 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)

Author

Rachid Touzani

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### 7.86.2 Constructor & Destructor Documentation

**Partition** ( **Mesh** & mesh, size\_t n, int verb = 0 )

Constructor to partition a mesh into submeshes.

Parameters

in	mesh	<b>Mesh</b> instance
in	n	Number of submeshes
in	verb	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>	<a href="#">Mesh</a> 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]

### 7.86.3 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

in	<i>sm</i>	Label of submesh
in	<i>label</i>	<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

in	<i>sm</i>	Submesh index
in	<i>i</i>	<a href="#">Side</a> label

Returns

Index of submesh

**Mesh& getSubMesh ( size\_t *i* ) const**

Return reference to submesh.

Parameters

in	<i>i</i>	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

in	<i>sm</i>	Index of submesh
in	<i>i</i>	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

in	<i>sm</i>	Label of submesh
in	<i>i</i>	<a href="#">Side</a> label

**int getNbConnectInSubMesh ( int *n*, int *s* ) const**

Get number of connected nodes in a submesh.

Parameters

in	<i>n</i>	Label of node for which connections are counted
in	<i>s</i>	Label of submesh (starting from 0)

**int getNbConnectOutSubMesh ( int *n*, int *s* ) const**

Get number of connected nodes out of a submesh.

Parameters

in	<i>n</i>	Label of node for which connections are counted
in	<i>s</i>	Label of submesh (starting from 0)

**void put ( size\_t *n*, string *file* ) const**

Save a submesh in file.

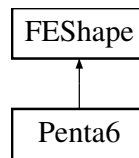
Parameters

in	$n$	Label of submesh
in	$file$	Name of file in which submesh is saved

## 7.87 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.*

### 7.87.1 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.

Author

Rachid Touzani

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### 7.87.2 Constructor & Destructor Documentation

**Penta6 ( const Element \* element )**

Constructor when data of **Element** e1 are given.

Parameters

in	<i>element</i>	Pointer to <b>Element</b>
----	----------------	---------------------------

### 7.87.3 Member Function Documentation

**void setLocal ( const Point< real.t > & s )**

Initialize local point coordinates in element.

Parameters

in	<i>s</i>	<b>Point</b> 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.

## 7.88 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.*

### 7.88.1 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

$T \leftrightarrow$	Data type (double, float, complex<double>, ...)
$_{-} \leftrightarrow$	

## 7.88.2 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

in	<i>nr</i>	Number of matrix rows.
in	<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

in	<i>size</i>	Number of matrix rows (and columns).
----	-------------	--------------------------------------

**PETScMatrix ( Mesh & *mesh*, size\_t *dof* = 0 )**

Constructor using a [Mesh](#) instance.

## Parameters

in	<i>mesh</i>	<a href="#">Mesh</a> instance from which matrix graph is extracted.
in	<i>dof</i>	Option parameter, with default value 0. 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

in	<i>I</i>	Vector containing pairs of row and column indices
in	<i>opt</i>	Flag indicating if vectors 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

### 7.88.3 Member Function Documentation

**void setAIJ ( const vector< int > & *nnz* )**

Parameters

in	<i>nnz</i>	
----	------------	--

**void setAIJ\_MPI ( const vector< int > & *diag\_nnz*, const vector< int > & *off\_nnz* )**

Parameters

in	<i>diag_nnz</i>	
in	<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

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. 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

in	<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

in	<i>np</i>	Total number of processors.
in	<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 `setPenal(..)`.

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

in	<i>x</i>	Vector to multiply by matrix
out	<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

in	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	Vector to add to the result. y 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

in	<i>a</i>	Constant to multiply by matrix
in	<i>x</i>	Vector to multiply by matrix
out	<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

in	<i>i</i>	Row index
in	<i>j</i>	Column index
in	<i>a</i>	Value to assign to $a(i, j)$

**void add ( size\_t *i*, size\_t *j*, const T\_ & *a* )**

Add a value to an entry of the matrix.

Parameters

in	<i>i</i>	Row index
in	<i>j</i>	Column index
in	<i>a</i>	Constant value to add to $a(i, j)$

**void set ( vector< int > & *ir*, vector< int > & *ic*, vector< T\_ > & *val* )**

Assign values to a portion of the matrix.

Parameters

in	<i>ir</i>	Vector of row indexes to assign (instance of class <code>vector</code> )
in	<i>ic</i>	Vector of column indexes to assign (instance of class <code>vector</code> )
in	<i>val</i>	Vector of values to assign (instance of class <code>vector</code> )

**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

in	$b$	Vector that contains right-hand side
out	$x$	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>
----	---------------	--

## Parameters

in	<i>prec</i>	Option to choose preconditioner in an enumerated variable <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 amount of computation needed</li> <li>• PCICC: Incomplete Cholesky factorization preconditioners</li> <li>• PCILU: Incomplete factorization preconditioners</li> <li>• PCASM: Use the (restricted) additive Schwarz method, each block is (approximately) solved with its own KSP object</li> <li>• PCLU: Uses a direct solver, based on LU factorization, as a preconditioner</li> <li>• PCCHOLESKY: Uses a direct solver, based on Cholesky factorization, as a preconditioner</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)

## 7.89 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** &m, 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.

### 7.89.1 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

$T \leftrightarrow$	Data type (double, int, complex<double>, ...)
$_{-} \leftrightarrow$	

## 7.89.2 Constructor &amp; Destructor Documentation

**PETScVect ( size\_t *n* )**

Constructor setting vector size.

## Parameters

in	<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

in	<i>nx</i>	Size for the first index
in	<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
----	-----------	--------------------------

Parameters

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
----	----------	-------------------------------

Parameters

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>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 !!

## 7.89.3 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
----	----------	------------------

## 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 ( 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	$m$	Instance of mesh
in	$code$	Code for which nodes will be assigned prescribed value
in	$exp$	Regular algebraic expression to prescribe
in	$dof$	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 (dof) 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 (dof) 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 (dof) 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.
----	----------	--------------------------------

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 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 $v(n,1) \cdot x$ , $v(n,2) \cdot y$ and $v(n,3) \cdot z$ are respectively the x and y and z derivatives at element n.
----	----------	---

**void getCurl ( 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 $v(n,1) \cdot x$ , $v(n,2) \cdot y$ and $v(n,3) \cdot z$ 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 <i>a</i> 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

in	<i>i</i>	Rank index in vector (starts at 1)
in	<i>a</i>	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

in	<i>i</i>	First index in vector (starts at 1)
in	<i>j</i>	Second index in vector (starts at 1)
in	<i>a</i>	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

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)
in	<i>a</i>	Value to assign

**void add ( size\_t *i*, T\_ *a* )**

Add a value to an entry for a 1-index vector.

Parameters

in	<i>i</i>	Rank index in vector (starts at 1)
----	----------	------------------------------------

Parameters

in	<i>a</i>	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

in	<i>i</i>	First index in vector (starts at 1)
in	<i>j</i>	Second index in vector (starts at 1)
in	<i>a</i>	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

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)
in	<i>a</i>	Value to assign

**T\_ operator[] ( size\_t *i* ) const**

Operator []

Parameters

in	<i>i</i>	Rank index in vector (starts at 0)
----	----------	------------------------------------

**T\_ operator() ( size\_t *i* ) const**

Operator ()

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 ) const**

Operator () with 2-D indexing (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) v( <i>i</i> , <i>j</i> ) starts at v(1,1) to v( <a href="#">getNx()</a> , <a href="#">getNy()</a> )

**T\_ operator() ( size\_t i, size\_t j, size\_t k ) const**

Operator () with 3-D indexing (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)
in	<i>k</i>	third index in vector (Number of vector components in the z-grid) 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> )

**PETScVect<T\_>& operator= ( const T\_ & a )**Operator =  
Assign a constant to vector entries

Parameters

in	<i>a</i>	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

in	<i>ii</i>	Vector containing indices where to insert (Note the indices start from 0 like any C-array)
in	<i>v</i>	Vector of values to insert, corresponding to indices in ii. Here the vector has entries of type Point<T_>.

**void Add ( const vector< int > & ii, const vector< T\_ > & v )**

Add values into certain locations of the vector.

Parameters

in	<i>ii</i>	Vector containing indices where to add (Note the indices start from 0 like any C-array)
in	<i>v</i>	Vector of values to add, corresponding to indices in ii

## 7.90 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.*

### 7.90.1 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

<a href="#">T_</a>	Data type (double, int, complex<double>, ...)
<a href="#">_</a>	

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)
- KSPLGMRES: The 'augmented' standard GMRES method where the subspace uses approximations to the error from previous restart cycles
- KSPTCQMR: A variant of QMR (quasi minimal residual) developed by Tony Chan
- KSPBCGS: The BiCGStab (Stabilized version of BiConjugate Gradient Squared) method
- 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)
- KSPFBCGS: The flexible BiCGStab method.
- KSPCGS: The CGS (Conjugate Gradient Squared) method
- KSPTFQMR: A transpose free QMR (quasi minimal residual)
- KSPCR: The conjugate residuals method
- KSPLSQR: The LSQR method
- KSPBICG: The Biconjugate gradient method (similar to running the conjugate gradient on the normal equations)
- KSPMINRES: The MINRES (Minimum Residual) method
- KSPSYMLQ: The SYMLQ method
- KSPGCR: 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



## 7.90.2 Constructor & Destructor Documentation

**PETScWrapper** ( int *argc*, char \*\* *args*, string *help* = "" )

Constructor with program arguments.

Parameters

in	<i>argc</i>	Count of number of command line arguments
----	-------------	---

## Parameters

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> [<code>noxterm</code>,<code>dbx</code>,<code>xdb</code>,<code>gdb</code>,...] <ul style="list-style-type: none"> <li>– Starts program in debugger</li> </ul> </li> <li>• <code>-on_error_attach_debugger</code> [<code>noxterm</code>,<code>dbx</code>,<code>xdb</code>,<code>gdb</code>,...] <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 <code>stderr</code> instead of the default <code>stdout</code></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> [<code>node1</code>,<code>node2</code>,...] - Indicates nodes to start in debugger</li> </ul> </li> <li>• <code>-debugger_pause</code> [<code>sleeptime</code>] (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 <code>malloc</code> (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 <code>malloc</code></li> </ul> </li> <li>• <code>-malloc.debug</code> <ul style="list-style-type: none"> <li>– check for memory corruption at EVERY <code>malloc</code> or <code>free</code></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></li> </ul>
964		<ul style="list-style-type: none"> <li>– Indicates not to trap error signals</li> <li>• <code>-shared.tmp</code> <ul style="list-style-type: none"> <li>– indicates <code>/tmp</code> directory is shared by all processors</li> </ul> </li> <li>• <code>-not_shared.tmp</code></li> </ul>

Parameters

in	<i>help</i>	String that contains message to display when argument -v is used
----	-------------	--

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

### 7.90.3 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	$p$	<a href="#">Partition</a> instance
----	-----	------------------------------------

**void setMatrix ( PETScMatrix< T\_ > & A )**

Define problem matrix.

Parameters

in	$A$	<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	$A$	<a href="#">PETScMatrix</a> instance that contains matrix
in	$b$	Vector containing the right-hand side
in	$s$	Option to choose iterative solver. See the definition of the class for iterative methods
in	$p$	Option to choose preconditioner. See the definition of the class for available preconditioners.
in	$tol$	Tolerance for convergence of iteration process [Default: $1.e-12$ ]
in	$max\_it$	Maximum number of linear solver iterations [Default: 1000]

**void setPreconditioner ( string  $p$  )**

Choose preconditioner for the iterative procedure.

Parameters

in	$p$	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	$tol$	Tolerance for convergence of iteration process
in	$max\_it$	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	<i>x</i>	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	<i>b</i>	Vector containing the right-hand side
in,out	<i>x</i>	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	<i>u</i>	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	<i>rel_tol</i>	Relative convergence tolerance, relative decrease in the preconditioned residual norm
----	----------------	---

Parameters

in	<i>abs_tol</i>	Absolute convergence tolerance of the preconditioned residual norm
in	<i>div_tol</i>	Divergence tolerance: Amount preconditioned residual norm
in	<i>max↔ _it</i>	Maximum number of iterations

## 7.91 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.*

### 7.91.1 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 has at least the member function

int [EnthalpyToTemperature](#)([real.t](#) &H, [real.t](#) &T, [real.t](#) &gamma)

### 7.91.2 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	<i>H</i>	Enthalpy value
out	<i>T</i>	Calculated temperature value
out	<i>gamma</i>	Maximal slope of the curve H -> 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 $H \rightarrow T$

## 7.92 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.

### 7.92.1 Detailed Description

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

Defines a point with arbitrary type coordinates.  
Operators = and () are overloaded.

Template Parameters

$T_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
$_{\leftrightarrow}$	

Author

Rachid Touzani

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### 7.92.2 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



### 7.92.3 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
----	---	--

## 7.93 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.*

### 7.93.1 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

$T_{\leftrightarrow}$ $_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
---	---

## Author

Rachid Touzani

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**7.93.2 Constructor & Destructor Documentation****Point2D (  $T\_a$ ,  $T\_b = T\_()$  )**

Constructor that assigns a, b to x-, y- and y-coordinates respectively.  
Default value for  $b$  is 0

**7.93.3 Member Function Documentation** **$T\_ \& \operatorname{operator}() ( \text{size\_t } i )$** 

Operator() : Non constant version.  
Values  $i = 1, 2$  correspond to x and y respectively

 **$\operatorname{const } T\_ \& \operatorname{operator}() ( \text{size\_t } i ) \operatorname{const}$** 

Operator() : Constant version.  
Values  $i=1, 2$  correspond to x and y respectively

 **$T\_ \& \operatorname{operator}[] ( \text{size\_t } i )$** 

Operator[]: Non constant version.  
Values  $i=0, 1$  correspond to x and y respectively

 **$\operatorname{const } T\_ \& \operatorname{operator}[] ( \text{size\_t } i ) \operatorname{const}$** 

Operator[] Constant version.  
Values  $i=0, 1$  correspond to x and y respectively

 **$\operatorname{Point2D}<T\_ > \& \operatorname{operator}= ( \operatorname{const } \operatorname{Point2D}<T\_ > \& p )$** 

Operator =  
Assign point p to current instance

 **$\operatorname{Point2D}<T\_ > \& \operatorname{operator}+= ( \operatorname{const } \operatorname{Point2D}<T\_ > \& p )$** 

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 )**

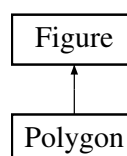
Operator !=

Return false if current instance is equal to p, true otherwise.

## 7.94 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.*

### 7.94.1 Detailed Description

To store and treat a polygonal figure.

### 7.94.2 Constructor & Destructor Documentation

`Polygon ( const Vect< Point< real.t > > &v, int code = 1 )`

Constructor.

Parameters

in	<i>v</i>	<code>Vect</code> instance containing list of coordinates of polygon vertices
in	<i>code</i>	Code to assign to the generated domain (Default value = 1)

### 7.94.3 Member Function Documentation

`void setVertices ( const Vect< Point< real.t > > &v )`

Assign vertices of polygon.

Parameters

in	<i>v</i>	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	<i>p</i>	<b>Point</b> <double> 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	<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 $\text{Prec}<T_-\>$ 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.*

### 7.95.1 Detailed Description

```
template<class T_>
class OFELI::Prec< T_ >
```

To set a preconditioner.

The preconditioner type is chosen in the constructor

Template Parameters

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



Author

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## 7.95.2 Constructor & Destructor Documentation

**Prec ( int *type* )**

Constructor that chooses preconditioner.

Parameters

in	<i>type</i>	Preconditioner type: <ul style="list-style-type: none"><li>• IDENT_PREC: Identity preconditioner (No preconditioning)</li><li>• DIAG_PREC: Diagonal preconditioner</li><li>• DILU_PREC: Diagonal Incomplete factorization preconditioner</li><li>• ILU_PREC: Incomplete factorization preconditioner</li><li>• SSOR_PREC: SSOR (Symmetric Successive Over Relaxation) preconditioner</li></ul>
----	-------------	--

**Prec ( const SpMatrix< T\_ > & A, int *type* = DIAG\_PREC )**

Constructor using matrix of the linear system to precondition.

Parameters

in	<i>A</i>	Matrix to precondition
in	<i>type</i>	Preconditioner type: <ul style="list-style-type: none"><li>• IDENT_PREC: Identity preconditioner (No preconditioning)</li><li>• DIAG_PREC: Diagonal preconditioner</li><li>• DILU_PREC: Diagonal Incomplete factorization preconditioner</li><li>• ILU_PREC: Incomplete factorization preconditioner</li><li>• SSOR_PREC: SSOR (Symmetric Successive Over Relaxation) preconditioner</li></ul>

**Prec ( const Matrix< T\_ > \* A, int *type* = DIAG\_PREC )**

Constructor using matrix of the linear system to precondition.

Parameters

in	<i>A</i>	Pointer to abstract <a href="#">Matrix</a> class to precondition
----	----------	--

Parameters

in	<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 (Symmetric Successive Over Relaxation) preconditioner</li> </ul>
----	-------------	---

### 7.95.3 Member Function Documentation

**void setType ( int *type* )**

Define preconditioner type.

Parameters

in	<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 (Symmetric Successive Over Relaxation) preconditioner</li> </ul>
----	-------------	---

**void setMatrix ( const Matrix< T\_ > \* *A* )**

Define pointer to matrix for preconditioning (if this one is abstract)

Parameters

in	<i>A</i>	Matrix to precondition
----	----------	------------------------

**void setMatrix ( const SpMatrix< T\_ > & *A* )**

Define the matrix for preconditioning.

Parameters

in	<i>A</i>	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

## 7.96 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)`

### 7.96.1 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.

Author

Rachid Touzani

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### 7.96.2 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

### 7.96.3 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). The values TRACTION and FLUX have the same effect.</li> <li>• BODY_FORCE: Read values for body (or volume) forces. 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	<i>v</i>	<a href="#">Vect</a> instance that is instantiatd on input and filled on output

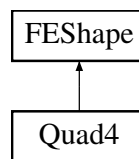
Parameters

in	<i>time</i>	Value of time for which data is read [Default: 0].
in	<i>dof</i>	DOF to store (Default is 0: All DOFs are chosen).

## 7.97 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](#) > &cs)  
*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.*

### 7.97.1 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.

Author

Rachid Touzani

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### 7.97.2 Constructor & Destructor Documentation

**Quad4 ( const Element \* *element* )**

Constructor when data of `Element` `e1` are given.

Parameters

in	<i>element</i>	Pointer to <code>Element</code>
----	----------------	---------------------------------

**Quad4 ( const Side \* *side* )**

Constructor when data of `Side` `sd` are given.

Parameters

in	<i>side</i>	Pointer to <code>Side</code>
----	-------------	------------------------------

### 7.97.3 Member Function Documentation

**void setLocal ( const Point< real\_t > & *s* )**

Initialize local point coordinates in element.

Parameters

in	<i>s</i>	<code>Point</code> in the reference element This function computes jacobian, shape functions and their partial derivatives at <code>s</code> . 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	<i>u</i>	Vector of values at nodes
in	<i>s</i>	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>i</i>	Local node label
in	<i>s</i>	<b>Point</b> 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.

## 7.98 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 P1 field to obtain a nodewise (Continuous P<sub>1</sub>) field by  $L^2$  projection.*

### 7.98.1 Detailed Description

To perform various reconstruction operations.

This class enables various reconstruction operations like smoothing, projections, ...

Author

Rachid Touzani

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### 7.98.2 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 P1 field to obtain a nodewise (Continuous P<sub>1</sub>) 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



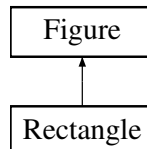
## Warning

This function is valid for  $P_1$  triangles (2-D) only.

## 7.99 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.*

### 7.99.1 Detailed Description

To store and treat a rectangular figure.

### 7.99.2 Constructor & Destructor Documentation

**Rectangle ( const Point< real.t > &bbm, const Point< real.t > &bbM, int code = 1 )**

Constructor.

Parameters

in	<i>bbm</i>	Left Bottom point of rectangle
in	<i>bbM</i>	Right Top point of rectangle
in	<i>code</i>	Code to assign to rectangle

### 7.99.3 Member Function Documentation

**void setBoundingBox ( const Point< real\_t > & *bbm*, const Point< real\_t > & *bbM* )**

Assign bounding box of the rectangle.

Parameters

in	<i>bbm</i>	Left Bottom point
in	<i>bbM</i>	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

## 7.100 Side Class Reference

To store and treat finite element sides (edges in 2-D or faces in 3-D)

### Public Types

### 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.*
- void `setOnBoundary` ()  
*Say that the side is on the boundary.*
- 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.*
- `int isReferenced ()`  
*Say if side has a nonzero code or not.*
- `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.*

### 7.100.1 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:

Author

Rachid Touzani

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### 7.100.2 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

### 7.100.3 Constructor & Destructor Documentation

**Side ( `size_t label`, `const string & shape` )**

Constructor initializing side label and shape.

Parameters

in	<i>label</i>	Label to assign to side.
in	<i>shape</i>	Shape of side (See class description).

**Side ( `size_t label`, `int shape` )**

Constructor initializing side label and shape.

Parameters

in	<i>label</i>	to assign to side.
in	<i>shape</i>	of side (See enum <code>ElementShape</code> in <a href="#">Mesh</a> ).

### 7.100.4 Member Function Documentation

**void DOF ( `size_t i`, `size_t dof` )**

Define label of DOF.

Parameters

in	<i>i</i>	DOF index
in	<i>dof</i>	Its label

**void setDOF ( `size_t &first_dof`, `size_t nb_dof` )**

Define number of DOF.

Parameters

in,out	<i>first_dof</i>	Label of the first DOF in input that is actualized
in	<i>nb_dof</i>	Number of DOF

**void setCode ( `size_t dof`, `int code` )**

Assign code to a DOF.

Parameters

in	<i>dof</i>	DOF to which code is assigned
in	<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

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
in	<i>dof</i>	Degree of Freedom for which code is assigned [Default: 1]

**void Add ( Element \* *el* )**

Set pointer to neighbor element.

Parameters

in	<i>el</i>	Pointer to element to add as a neighbor element
----	-----------	---

Remarks

This function adds the pointer *el* only if this one is not a null pointer

**void set ( Element \* *el*, size\_t *i* )**

Set pointer to neighbor element.

Parameters

in	<i>el</i>	Pointer to element to set as a neighbor element
in	<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

in	<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

in	<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

in	<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
----	----	---------------------------

## 7.101 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)*

### 7.101.1 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.

Author

Rachid Touzani

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### 7.101.2 Member Function Documentation

**void selectCode ( int code, int dof = 1 )**

Select sides having a given code for a given degree of freedom.

Parameters

in	<i>code</i>	Code that sides share
in	<i>dof</i>	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.

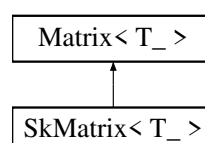
Parameters

in	<i>code</i>	Code of sides to exclude
in	<i>dof</i>	Degree of Freedom label [Default: 1]

## 7.102 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.*

  - virtual void [reset](#) ()

*Set matrix to 0 and reset factorization parameter.*

  - 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).*

  - virtual void [clear](#) ()

*brief Set all matrix entries to zero*

  - 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 -=.*

7.102.1 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

$T_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
$_{\leftrightarrow}$	

Author

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7.102.2 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

in	size	Number of matrix rows (and columns).
in	is_diagonal	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

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. 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.

**SkMatrix ( const Vect< size\_t > & ColHt )**

Constructor that initializes skyline structure of matrix using vector of column heights.

Parameters

in	<i>ColHt</i>	<a href="#">Vect</a> instance that contains rows lengths of matrix.
----	--------------	---

**7.102.3 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. 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

in	<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, j)

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 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	<i>a</i>	Scalar to premultiply
in	<i>m</i>	Matrix by which a 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. y 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	<i>a</i>	Constant to multiply by matrix
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 Mult ( const Vect< T\_ > & *x*, Vect< T\_ > & *y* ) const** [virtual]

Multiply matrix by vector *x* and save in *y*.

Parameters

in	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	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	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	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>i</i>	Row index
----	----------	-----------

Parameters

in	<i>j</i>	Column index
in	<i>val</i>	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>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\\_ >](#).

**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) 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) 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.



Skyline of matrix is stored row by row.

**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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>	Side 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 [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 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 homogeneous (=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>	Vect 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 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>	Vect instance that contains right-hand side.
in	<i>u</i>	Vect 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) 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]

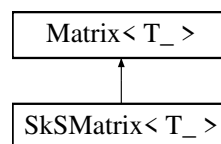
Operator -=.

Subtract constant value *x* from all matrix entries.

## 7.103 SkSMatrix< T\_ > Class Template Reference

To handle symmetric matrices in skyline storage format.

Inheritance diagram for SkSMatrix< T\_ >:



### Public Member Functions

- [SkSMatrix](#) ()  
*Default constructor.*
- [SkSMatrix](#) (size\_t [size](#), int is\_diagonal=false)  
*Constructor that initializes a dense symmetric matrix.*
- [SkSMatrix](#) (Mesh &mesh, size\_t dof=0, int is\_diagonal=false)  
*Constructor using mesh to initialize skyline structure of matrix.*
- [SkSMatrix](#) (const Vect< size\_t > &ColHt)  
*Constructor that initializes skyline structure of matrix using vector of column height.*
- [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.*
- [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.*
- [SkSMatrix](#) (const SkSMatrix< T\_ > &m)  
*Copy Constructor.*
- [~SkSMatrix](#) ()  
*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 **SksMatrix**< 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\*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.*
- virtual void [reset](#) ()  
*Set matrix to 0 and reset factorization parameter.*
- 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).*
- virtual void [clear](#) ()  
*brief Set all matrix entries to zero*
- 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 -=.*

### 7.103.1 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

$T \leftrightarrow$	Data type (double, float, complex<double>, ...)
$\_ \leftrightarrow$	

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### 7.103.2 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

in	<i>size</i>	Number of matrix rows (and columns).
in	<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

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. 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.

#### **SkMatrix ( 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.
----	--------------	---

#### **SkMatrix ( 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). 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). In the latter case, these vectors can contain the same contents more than once and are not necessarily ordered

### 7.103.3 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. 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	<i>a</i>	Constant to multiply by matrix
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 Mult ( const Vect< T\_ > & x, Vect< T\_ > & y ) const** [virtual]

Multiply matrix by vector x and save in y

Parameters

in	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	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	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	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>i</i>	Row index
in	<i>j</i>	Column index
in	<i>val</i>	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>i</i>	Row index
in	<i>j</i>	Column index



## Warning

To modify a value of an entry of the matrix it is safer not to modify both lower and upper triangles. Otherwise, wrong values will be assigned. If not sure, use the member functions `set` or `add`.

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	$b$	<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
- 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	$b$	<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\_ > &  $x$  )** [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 `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	$b$	<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.

Implements [Matrix< T\\_ >](#).

**T\_\* get ( ) const**

Return C-Array.

Skyline of matrix is stored row by row.

**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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 `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 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 ( <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 ( <i>dof</i> >0) or both matrix and right-hand side ( <i>dof</i> =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 ( <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

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 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]

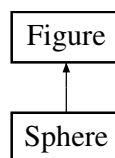
Operator -=.

Subtract constant value x from all matrix entries.

## 7.104 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.*

### 7.104.1 Detailed Description

To store and treat a sphere.

### 7.104.2 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]

### 7.104.3 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

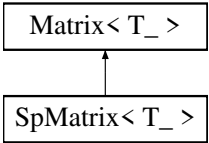
in	<i>p</i>	<a href="#">Point</a> for which distance is computed
in	<i>a</i>	First vertex of line
in	<i>b</i>	Second vertex of line

Returns

Signed distance

## 7.105 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](#) (const [SpMatrix](#) &m)  
*Copy constructor.*
- [~SpMatrix](#) ()  
*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 [Vect](#)< 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\\_ > &x](#), [Vect< T\\_ > &y](#)) 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  $\alpha \cdot x$  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](#) (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.*
- `virtual void reset ()`  
*Set matrix to 0 and reset factorization parameter.*
- `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.*
- `virtual int solve (Vect< T_ > &b)=0`  
*Solve the linear system.*
- `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)`

### 7.105.1 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

$T \leftrightarrow$	Data type (double, float, <code>complex&lt;double&gt;</code> , ...)
$\_ \leftrightarrow$	

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## 7.105.2 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

in	<i>nr</i>	Number of matrix rows.
in	<i>nc</i>	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

in	<i>size</i>	Number of matrix rows (and columns).
in	<i>is_diagonal</i>	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

in	<i>mesh</i>	<a href="#">Mesh</a> instance from which matrix graph is extracted.
in	<i>dof</i>	Option parameter, with default value 0. 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.

### 7.105.3 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. 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 **setPenal(..)**.

Parameters

in	<i>mesh</i>	<a href="#">Mesh</a> instance from which information is extracted.
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.

**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 conatins imposed valued 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 Vect< 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	$a$	Constant to multiply matrix by
----	-----	--------------------------------

Returns

Resulting matrix

**void Mult ( const Vect< T\_ > &  $x$ , Vect< T\_ > &  $y$  ) const** [virtual]

Multiply matrix by vector and save in another one.

Parameters

in	$x$	Vector to multiply by matrix
out	$y$	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	<i>x</i>	Vector to multiply by matrix
out	<i>y</i>	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	<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 <a href="#">Matrix</a> by which <i>a</i> 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>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 add ( size\_t *i*, size\_t *j*, const T\_ & *val* )** [virtual]

Add a value to an entry of the matrix.

Parameters

in	<i>i</i>	Row index
----	----------	-----------

Parameters

in	$j$	Column index
in	$val$	Constant value to add to $a(i, j)$

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 ( const Vect< T\_ > & b, Vect< T\_ > & x )** [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

in	$b$	Vector that contains right-hand side
out	$x$	Vector that contains the obtained solution

Returns

Number of actual performed iterations

Implements [Matrix< T\\_ >](#).

**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\\_ >](#).**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

## Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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 **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 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.
--------	----------	--

## Parameters

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 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) 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(..)`.

**virtual int solve ( Vect< T\_ > & b )** [pure virtual], [inherited]

Solve the linear system.

If the inherited class is [SpMatrix](#), the function uses an iterative method once this one has been chosen. Otherwise, the method solves the linear system by factorization.

Implemented in [SkSMatrix< T\\_ >](#), [SkMatrix< T\\_ >](#), [DMatrix< T\\_ >](#), [DSMatrix< T\\_ >](#), [TrMatrix< T\\_ >](#), and [BMatrix< T\\_ >](#).

**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>	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* )** [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.

**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.

## 7.106 SteklovPoincare2DBE Class Reference

Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.

### 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.*

### 7.106.1 Detailed Description

Solver of the Steklov Poincare problem in 2-D geometries using piecewise constant boundary elemen.

[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.

Author

Rachid Touzani

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### 7.106.2 Constructor & Destructor Documentation

**SteklovPoincare2DBE ( `bool ext = false` )**

Default Constructor.

Parameters

in	<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

in	<i>mesh</i>	Reference to mesh instance.
in	<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

in	<i>mesh</i>	Reference to mesh instance.
in	<i>g</i>	<a href="#">Vect</a> instance that contains imposed solution on the boundary
in	<i>b</i>	<a href="#">Vect</a> instance that contains the left hand side in input and the solution in output
in	<i>ext</i>	Boolean variable to say if the domain is external (true) or internal (false: Default value).

### 7.106.3 Member Function Documentation

**void setMesh ( `const Mesh & mesh, bool ext = false` )**

set [Mesh](#) instance

Parameters

in	<i>mesh</i>	<a href="#">Mesh</a> instance
in	<i>ext</i>	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	<code>g</code>	Vector that contains imposed solution on the boundary
in	<code>b</code>	Vector that contains the left hand side in input and the solution in output

## 7.107 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.*

### 7.107.1 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>`".

Author

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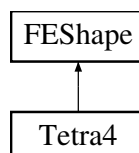
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## 7.108 Tetra4 Class Reference

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.*

### 7.108.1 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.

Author

Rachid Touzani

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### 7.108.2 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

in	$k$	Local edge number for which the edge shape function is computed
in	$s$	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

in	$k$	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.

## 7.109 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)*

### 7.109.1 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.

Author

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### 7.109.2 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

## 7.110 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 [setLinearSolver](#) ([LinearSolver](#)< [real\\_t](#) > &ls)



- Set reference to [LinearSolver](#) instance.*

  - void [setPDE](#) ([AbsEqua](#)< [real.t](#) > &eq, bool nl=false)

*Define partial differential equation to solve.*
- void [setRK4RHS](#) ([Vect](#)< [real.t](#) > &f)

*Set intermediate right-hand side vector for the Runge-Kutta method.*
- void [setRK3\\_TVDRHS](#) ([Vect](#)< [real.t](#) > &f)

*Set intermediate right-hand side vector for the TVD Runge-Kutta 3 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 [setNLTerm0](#) ([Vect](#)< [real.t](#) > &a0, [Matrix](#)< [real.t](#) > &A0)

*Set vectors defining a nonlinear first order system of ODEs.*
- void [setNLTerm](#) ([Vect](#)< [real.t](#) > &a0, [Vect](#)< [real.t](#) > &a1, [Vect](#)< [real.t](#) > &a2)

*Set vectors defining a nonlinear second order system of ODEs.*
- 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.*

### 7.110.1 Detailed Description

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

Author

Rachid Touzani

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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*)

### 7.110.2 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 <i>theTimeStep</i>
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 <i>theFinalTime</i>

### 7.110.3 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 if 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 setLinearSolver ( LinearSolver< real.t > &ls )**

Set reference to [LinearSolver](#) instance.

Parameters

in	<i>ls</i>	Reference to <a href="#">LinearSolver</a> instance
----	-----------	--

**void setPDE ( AbsEqua< real.t > &eq, bool nl = false )**

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
in	<i>nl</i>	Toggle to say if the considered equation is linear [Default: 0] or not

**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 setRK3\_TVDRHS ( Vect< real.t > &f )**

Set intermediate right-hand side vector for the TVD Runge-Kutta 3 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	$u$	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

in	$u$	Vector containing initial condition for the unknown
in	$v$	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

in	$f$	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

in	$\beta$	Parameter beta [Default: 0.25]
----	---------	--------------------------------

Parameters

in	<i>gamma</i>	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	<i>s</i>	Solver identification parameter. To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER [Default: DIRECT_SOLVER]
in	<i>p</i>	Preconditioner identification parameter. To be chosen in the enumeration variable Preconditioner: IDENT_PREC, DIAG_PREC, ILU_PREC [Default: DIAG_PREC]

Note

The argument *p* has no effect if the solver is DIRECT\_SOLVER

**void setNLTerm0 ( Vect< real.t > & *a0*, Matrix< real.t > & *A0* )**

Set vectors defining a nonlinear first order system of ODEs.

The ODE system has the form  $a1(u)' + a0(u) = 0$

Parameters

in	<i>a0</i>	<a href="#">Vect</a> instance defining the 0-th order term
in	<i>A0</i>	<a href="#">Matrix</a> instance

**void setNLTerm ( Vect< real.t > & *a0*, Vect< real.t > & *a1*, Vect< real.t > & *a2* )**

Set vectors defining a nonlinear second order system of ODEs.

The ODE system has the form  $a2(u)'' + a1(u)' + a0(u) = 0$

Parameters

in	<i>a0</i>	<a href="#">Vect</a> instance defining the 0-th order term
in	<i>a1</i>	<a href="#">Vect</a> instance defining the first order term
in	<i>a2</i>	<a href="#">Vect</a> instance defining the second order term

**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

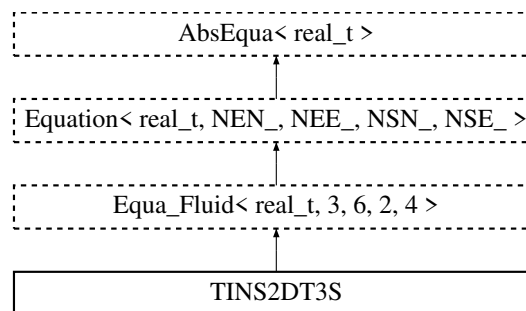
Parameters

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 [Default: NULL]

## 7.111 TINS2DT3S Class Reference

Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

Inheritance diagram for TINS2DT3S:



### Public Member Functions

- [TINS2DT3S](#) ()  
*Default Constructor.*
- [TINS2DT3S](#) (Mesh &mesh, Vect< real\_t > &u, Vect< real\_t > &p, real\_t &ts, real\_t Re=0.)  
*Constructor using mesh.*
- [~TINS2DT3S](#) ()  
*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< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const Vect< real\_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](#)< [real\\_t](#) > &b)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEN\\_](#) > &be, int dof)

*Localize Element Vector from a Vect instance.*
- void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NEN\\_](#) > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementSideVector](#) (const [Vect](#)< [real\\_t](#) > &b, [LocalVect](#)< [real\\_t](#), [NSE\\_](#) > &be)

*Localize Element Vector from a Vect instance.*
- void [ElementVector](#) (const [Vect](#)< [real\\_t](#) > &b, int dof.type=NODE.FIELD, int flag=0)

*Localize Element Vector.*
- void [SideVector](#) (const [Vect](#)< [real\\_t](#) > &b)

*Localize Side Vector.*
- void [ElementNodeCoordinates](#) ()

*Localize coordinates of element nodes.*
- void [SideNodeCoordinates](#) ()

*Localize coordinates of side nodes.*
- void [ElementAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)

*Assemble element right-hand side vector into global one.*
- void [ElementAssembly](#) ([BMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([SpMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([TrMatrix](#)< [real\\_t](#) > &A)

*Assemble element matrix into global one.*
- void [ElementAssembly](#) ([Vect](#)< [real\\_t](#) > &v)

*Assemble element vector into global one.*
- void [SideAssembly](#) ([PETScMatrix](#)< [real\\_t](#) > &A)

*Assemble side matrix into global one.*
- void [SideAssembly](#) ([PETScVect](#)< [real\\_t](#) > &b)

*Assemble side right-hand side vector into global one.*
- void [SideAssembly](#) ([Matrix](#)< [real\\_t](#) > \*A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkSMatrix](#)< [real\\_t](#) > &A)

*Assemble side (edge or face) matrix into global one.*
- void [SideAssembly](#) ([SkMatrix](#)< [real\\_t](#) > &A)



- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SpMatrix](#)< [real.t](#) > &A)
- Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([Vect](#)< [real.t](#) > &v)
- Assemble side (edge or face) vector into global one.*

  - void [DGElementAssembly](#) ([Matrix](#)< [real.t](#) > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SkSMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SkMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([SpMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*

  - void [DGElementAssembly](#) ([TrMatrix](#)< [real.t](#) > &A)
- Assemble product of element matrix by element vector into global vector.*

  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real.t](#) > &x, [Vect](#)< [real.t](#) > &b)
- Assemble product of side matrix by side vector into global vector.*

  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real.t](#) > &x, [Vect](#)< [real.t](#) > &b)
- Return number of element nodes.*

  - [size.t](#) [getNbNodes](#) () const
- Return number of element equations.*

  - [size.t](#) [getNbEq](#) () const
- Set initial solution (previous time step)*

  - void [setInitialSolution](#) (const [Vect](#)< [real.t](#) > &u)
- Define a material property by an algebraic expression.*

  - [real.t](#) [setMaterialProperty](#) (const string &exp, const string &prop)
- Define mesh and renumber DOFs after removing imposed ones.*

  - void [setMesh](#) ([Mesh](#) &m)
- Return reference to Mesh instance.*

  - [Mesh](#) & [getMesh](#) () const
- Return reference to linear solver instance.*

  - [LinearSolver](#)< [real.t](#) > & [getLinearSolver](#) ()
- Choose solver for the linear system.*

  - void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)
- Choose type of matrix.*

  - void [setMatrixType](#) (int t)
- Solve the linear system with given matrix and right-hand side.*

  - int [solveLinearSystem](#) ([Matrix](#)< [real.t](#) > \*A, [Vect](#)< [real.t](#) > &b, [Vect](#)< [real.t](#) > &x)
- Solve the linear system with given right-hand side.*

  - int [solveLinearSystem](#) ([Vect](#)< [real.t](#) > &b, [Vect](#)< [real.t](#) > &x)

## Public Attributes

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

### 7.111.1 Detailed Description

Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 2-D domains. Numerical approximation uses stabilized 3-node triangle finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

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Rachid Touzani

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### 7.111.2 Constructor & Destructor Documentation

**TINS2DT3S** ( *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 <i>Re</i> has any other value, then nondimensional form of the equations is assumed and material properties are ignored.

### 7.111.3 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*< *real.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< real.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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real.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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes SkSMatrix, SkMatrix, SpMatrix)
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.



## Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

## Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

## Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

## Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real.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< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkSMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SkMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( SpMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable theSide

**void SideAssembly ( Vect< real.t > & *v* )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element &  $el$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	$el$	Reference to Element instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector to add (Vect instance)

**void AxbAssembly ( const Side &  $sd$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	$sd$	Reference to Side instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.111.4 Member Data Documentation

**LocalVect<real.t,NEE-> ePrev** [inherited]

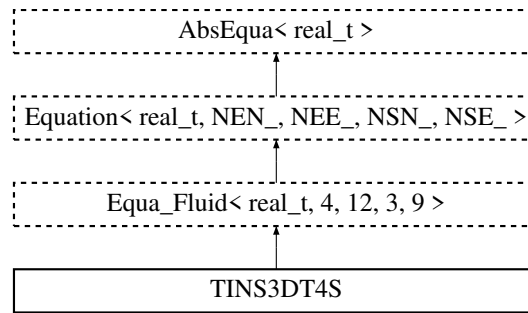
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

## 7.112 TINS3DT4S Class Reference

Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

Inheritance diagram for TINS3DT4S:



## Public Member Functions

- **TINS3DT4S** ()  
*Default Constructor.*
- **TINS3DT4S** (Mesh &mesh, Vect< real\_t > &u, Vect< real\_t > &p, real\_t &ts, real\_t Re=0.)  
*Constructor using mesh.*
- **~TINS3DT4S** ()  
*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< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void **updateBC** (const Vect< real\_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< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVector** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be, int dof)  
*Localize Element Vector from a Vect instance.*
- void **ElementNodeVectorSingleDOF** (const Vect< real\_t > &b, LocalVect< real\_t, NEN\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementSideVector** (const Vect< real\_t > &b, LocalVect< real\_t, NSE\_ > &be)  
*Localize Element Vector from a Vect instance.*
- void **ElementVector** (const Vect< real\_t > &b, int dof\_type=NODE.FIELD, int flag=0)  
*Localize Element Vector.*
- void **SideVector** (const Vect< real\_t > &b)  
*Localize Side Vector.*
- void **ElementNodeCoordinates** ()  
*Localize coordinates of element nodes.*

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



- void **AxbAssembly** (const **Side** &sd, const **Vect**< **real.t** > &x, **Vect**< **real.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**< **real.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**< **real.t** > & **getLinearSolver** ()  
*Return reference to linear solver instance.*
- void **setSolver** (**Iteration** ls, **Preconditioner** pc=**IDENT\_PREC**)  
*Choose solver for the linear system.*
- void **setMatrixType** (int t)  
*Choose type of matrix.*
- int **solveLinearSystem** (**Matrix**< **real.t** > \*A, **Vect**< **real.t** > &b, **Vect**< **real.t** > &x)  
*Solve the linear system with given matrix and right-hand side.*
- int **solveLinearSystem** (**Vect**< **real.t** > &b, **Vect**< **real.t** > &x)  
*Solve the linear system with given right-hand side.*

## Public Attributes

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

### 7.112.1 Detailed Description

Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tetrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

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Rachid Touzani

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### 7.112.2 Constructor & Destructor Documentation

**TINS3DT4S** ( [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.

### 7.112.3 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). NOT IMPLEMENTED</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< real.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< real.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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with Element was invoked.
----	----------	--

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real.t > & b, LocalVect< real.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< real\_t > & b, LocalVect< real\_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< real\_t > & b, LocalVect< real\_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< real\_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< real\_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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

## Parameters

A	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as a BMatrix instance
----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble element matrix into global one.

## Parameters

<i>A</i>	Global matrix stored as an SkSMatrix instance
----------	---

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an TrMatrix instance
----	----------	--

## Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( Vect< real.t > & v )** [inherited]

Assemble element vector into global one.

## Parameters

in	<i>v</i>	Global vector (Vect instance)
----	----------	-------------------------------



## Warning

The element pointer is given by the global variable `theElement`

**void SideAssembly ( PETScMatrix< real\_t > &A )** [inherited]

Assemble side matrix into global one.

## Parameters

<i>A</i>	Reference to global matrix
----------	----------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( PETScVect< real\_t > &b )** [inherited]

Assemble side right-hand side vector into global one.

## Parameters

<i>b</i>	Reference to global right-hand side vector
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Matrix< real\_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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real\_t > &A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

<i>in</i>	<i>A</i>	Global matrix stored as an SkSMatrix instance
-----------	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	A	Global matrix stored as an SpMatrix instance
----	---	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & v )** [inherited]

Assemble side (edge or face) vector into global one.

## Parameters

in	v	Global vector (Vect instance)
----	---	-------------------------------

## Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>A</code>	Global matrix stored as an SkSMatrix instance
----------------	---

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SkMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an SpMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real\_t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

## Parameters

<code>in</code>	<code>A</code>	Global matrix stored as an TrMatrix instance
-----------------	----------------	--

## Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element & *el*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

## Parameters

in	<i>el</i>	Reference to Element instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector to add (Vect instance)

**void AxbAssembly ( const Side & *sd*, const Vect< real.t > & *x*, Vect< real.t > & *b* )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

## Parameters

in	<i>sd</i>	Reference to Side instance
in	<i>x</i>	Global vector to multiply by (Vect instance)
out	<i>b</i>	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & b, Vect< real.t > & x )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.112.4 Member Data Documentation

**LocalVect<real.t,NEE-> ePrev** [inherited]

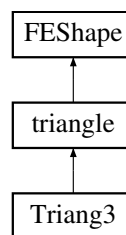
LocalVect instance containing local vector associated to current element.

This vector has been stored as the one at previous iteration or previous time step

### 7.113 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.*

### 7.113.1 Detailed Description

Defines a 3-Node ( $P_1$ ) triangle.

The reference element is the rectangle triangle with two unit edges.

Author

Rachid Touzani

Copyright

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### 7.113.2 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.

### 7.113.3 Member Function Documentation

**real\_t Sh ( size\_t *i*, Point< real\_t > *s* ) const**

Calculate shape function of node at a given point.

Parameters

in	<i>i</i>	Label (local) of node
in	<i>s</i>	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

in	<i>u</i>	Local vector for which the gradient is evaluated
----	----------	--

**real\_t getDet ( ) const** [inherited]

Return determinant of jacobian.

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** [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]

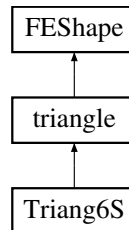
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.114 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.*

### 7.114.1 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.

Author

Rachid Touzani

Copyright

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### 7.114.2 Constructor & Destructor Documentation

**Triang6S ( const Element \* el )**

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

Parameters

in	<i>el</i>	Pointer to <a href="#">Element</a> instance
----	-----------	---

### 7.114.3 Member Function Documentation

**real.t Sh ( size\_t i, const Point< real.t > &s ) const**

Calculate shape function of a node.

Parameters

in	<i>i</i>	Local label of the node $1 \leq i \leq 6$
in	<i>s</i>	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

in	<i>i</i>	Local label of node
in	<i>s</i>	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

in	<i>s</i>	Local coordinates of the point where the gradient of the shape function is evaluated
in	<i>u</i>	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

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]

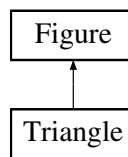
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

## 7.115 Triangle Class Reference

To store and treat a triangle.

Inheritance diagram for Triangle:



### Public Member Functions

- **Triangle ()**  
*Default constructor.*
- **Triangle (const Point< real\_t > &v1, const Point< real\_t > &v2, const Point< real\_t > &v3, int code=1)**  
*Constructor with vertices and code.*
- **void setVertex1 (const Point< real\_t > &v)**  
*Assign first vertex of triangle.*
- **void setVertex2 (const Point< real\_t > &v)**  
*Assign second vertex of triangle.*
- **void setVertex3 (const Point< real\_t > &v)**  
*Assign third vertex of triangle.*
- **real\_t getSignedDistance (const Point< real\_t > &p) const**  
*Return signed distance of a given point from the current triangle.*
- **Triangle & operator+= (Point< real\_t > a)**  
*Operator +=.*
- **Triangle & 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.*

### 7.115.1 Detailed Description

To store and treat a triangle.

### 7.115.2 Constructor & Destructor Documentation

#### Triangle ( )

Default constructor.

Constructs a unit triangle with vertices (0,0), (1,0) and (0,1)

**Triangle ( const Point< real\_t > &v1, const Point< real\_t > &v2, const Point< real\_t > &v3, int code = 1 )**

Constructor with vertices and code.

Parameters

in	<i>v1</i>	Coordinates of first vertex of triangle
in	<i>v2</i>	Coordinates of second vertex of triangle
in	<i>v3</i>	Coordinates of third vertex of triangle
in	<i>code</i>	Code to assign to the generated figure [Default: 1]

Remarks

Vertices must be given in counterclockwise order

### 7.115.3 Member Function Documentation

**real\_t getSignedDistance ( const Point< real\_t > &p ) const** [virtual]

Return signed distance of a given point from the current triangle.

The computed distance is negative if p lies in the triangle, positive if it is outside, and 0 on its boundary

Parameters

in	<i>p</i>	Point<double> instance
----	----------	------------------------

Reimplemented from [Figure](#).

**Triangle& operator+= ( Point< real\_t > a )**

Operator +=.

Translate triangle by a vector a

**Triangle& operator+= ( real\_t a )**

Operator \*+=.

Scale triangle 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
----	----------	-------------------------------

Parameters

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

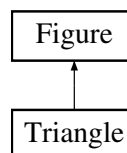
Returns

Signed distance

## 7.116 Triangle Class Reference

To store and treat a triangle.

Inheritance diagram for Triangle:



### Public Member Functions

- [Triangle](#) ()  
*Default constructor.*
- [Triangle](#) (const [Point](#)< [real\\_t](#) > &v1, const [Point](#)< [real\\_t](#) > &v2, const [Point](#)< [real\\_t](#) > &v3, int code=1)  
*Constructor with vertices and code.*
- void [setVertex1](#) (const [Point](#)< [real\\_t](#) > &v)  
*Assign first vertex of triangle.*
- void [setVertex2](#) (const [Point](#)< [real\\_t](#) > &v)  
*Assign second vertex of triangle.*
- void [setVertex3](#) (const [Point](#)< [real\\_t](#) > &v)  
*Assign third vertex of triangle.*
- [real\\_t](#) [getSignedDistance](#) (const [Point](#)< [real\\_t](#) > &p) const

*Return signed distance of a given point from the current triangle.*

- **Triangle** & **operator+=** (**Point**< **real\_t** > a)

*Operator +=.*

- **Triangle** & **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.*

### 7.116.1 Detailed Description

To store and treat a triangle.

### 7.116.2 Constructor & Destructor Documentation

**Triangle** ( )

Default constructor.

Constructs a unit triangle with vertices (0,0), (1,0) and (0,1)

**Triangle** ( const **Point**< **real\_t** > &*v1*, const **Point**< **real\_t** > &*v2*, const **Point**< **real\_t** > &*v3*, int *code* = 1 )

Constructor with vertices and code.

Parameters

in	<i>v1</i>	Coordinates of first vertex of triangle
in	<i>v2</i>	Coordinates of second vertex of triangle
in	<i>v3</i>	Coordinates of third vertex of triangle
in	<i>code</i>	Code to assign to the generated figure [Default: 1]

Remarks

Vertices must be given in counterclockwise order

### 7.116.3 Member Function Documentation

**real\_t** **getSignedDistance** ( const **Point**< **real\_t** > &*p* ) const [virtual]

Return signed distance of a given point from the current triangle.

The computed distance is negative if *p* lies in the triangle, positive if it is outside, and 0 on its boundary

Parameters

in	<i>p</i>	<b>Point</b> <double> instance
----	----------	--------------------------------

Reimplemented from [Figure](#).

**Triangle& operator+= ( Point< real\_t > a )**

Operator +=.

Translate triangle by a vector a

**Triangle& operator+= ( real\_t a )**

Operator \*+=.

Scale triangle 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

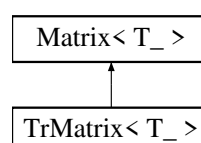
Returns

Signed distance

## 7.117 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.*
- `virtual void reset ()`  
*Set matrix to 0 and reset factorization parameter.*
- `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).*
- `virtual void clear ()`  
*brief Set all matrix entries to zero*
- `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 -=.

### 7.117.1 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. Any matrix entry can be accessed by the () operator: For instance, if A is an instance of this class, A(i, j) stands for the entry at the i-th row and j-th column, i and j starting from 1. If its difference from i-1, i or i+1, the returned value is 0. Entries of A can be assigned a value by the same operator. Only nonzero entries can be assigned.

Template Parameters

$T_{\leftrightarrow}$	Data type (double, float, complex<double>, ...)
$_{\leftrightarrow}$	

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### 7.117.2 Constructor & Destructor Documentation

#### TrMatrix ( )

Default constructor.

Initialize a zero dimension tridiagonal matrix

### 7.117.3 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	<i>h</i>	Mesh size (assumed constant)
----	----------	------------------------------

#### void setSize ( size.t size )

Set size (number of rows) of matrix.

Parameters

in	<i>size</i>	Number of rows and columns.
----	-------------	-----------------------------

#### void Axy ( T\_ a, const TrMatrix< 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 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\\_ >](#).**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	$b$	<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.

**Warning:** Matrix is modified after this function.

Implements [Matrix< T\\_ >](#).

**int solve ( const Vect< T\_ > & b, Vect< T\_ > & x )** [virtual]

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.

Implements [Matrix< T\\_ >](#).

**virtual void reset ( )** [virtual], [inherited]

Set matrix to 0 and reset factorization parameter.

Warning

This function must be used if after a factorization, the matrix has modified

Reimplemented in [DMatrix< 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 `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 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.



## Parameters

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

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 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.

## 7.118 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  $\mathbf{x}$ , 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  $\mathbf{x}$ , 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  $\mathbf{x}$ , 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  $\mathbf{x}$ , for DOF `dof`*

### 7.118.1 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 inherits from the present one where the virtual functions are implemented.

Template Parameters

$T_ \leftrightarrow$	Data type (real.t, float, complex<real.t>, ...)
$_ \leftrightarrow$	

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### 7.118.2 Constructor & Destructor Documentation

**UserData ( const class Mesh & *mesh* )**

Constructor using mesh instance.

Parameters

<i>mesh</i>	Reference to <a href="#">Mesh</a> instance
-------------	--

### 7.118.3 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 Boundary↵  
Condition 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	<i>x</i>	Coordinates of point at which the body force is given
in	<i>time</i>	Value of time [Default: 0.]
in	<i>dof</i>	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

## 7.119 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** (Grid &g)  
*Constructor with a Grid instance.*
- **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** (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.*
- bool **isGrid** () const  
*Say if vector is constructed for a grid.*
- 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 **setIJK** (const string &exp)  
*Assign a given function (given by an interpretable algebraic expression) of indices components of vector.*
- void **setNodeBC** (Mesh &m, int code, T\_ val, size\_t dof=1)  
*Assign a given value to components of vector with given code.*
- void **setSideBC** (Mesh &m, int code, T\_ val, size\_t dof=1)  
*Assign a given value to components of vector corresponding to sides 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 **setSideBC** (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 corresponding to sides 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 **setSideBC** (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 **setSideBC** (int code, T\_ val, size\_t dof=1)  
*Assign a given value 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.*
- 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_ vmax, size_t n)`  
*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.*
- `Vect< complex_t > getFFT ()`  
*Compute FFT transform of vector.*
- `Vect< complex_t > getInvFFT ()`  
*Compute Inverse FFT transform of vector.*
- `operator VectorX () const`  
*Casting operator.*

### 7.119.1 Detailed Description

`template<class T_>`  
`class OFELI::Vect< T_ >`

To handle general purpose vectors.

Author

Rachid Touzani

Copyright

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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  $\times$  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

$T \leftrightarrow$	Data type (real_t, float, complex<real_t>, ...)
$_{-} \leftrightarrow$	

## 7.119.2 Constructor & Destructor Documentation

**Vect ( size\_t n )**

Constructor setting vector size.

Parameters

in	<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

in	<i>nx</i>	Size for the first index
in	<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

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

**Vect ( size\_t n, T\_ \* x )**

Create an instance of class [Vect](#) 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

**Vect ( Grid & g )**

Constructor with a [Grid](#) instance.

The constructed vector has as size the total number of grid nodes

## Parameters

in	<i>g</i>	<a href="#">Grid</a> instance
----	----------	-------------------------------

**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 nb_dof 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: NODE_FIELD, ELEMENT_FIELD, SIDE_FIELD or EDGE_FIELD (Default: NODE_FIELD)

**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.

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)

**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 <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 <code>d=201</code> 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>v</i> . 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](#)

**7.119.3 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 <code>first_dof=2</code> and <code>nb_dof=1</code> 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 <i>x</i> , <i>y</i> , <i>z</i> which are coordinates of nodes and <i>t</i> 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 values of vector. This expression must use the variable x as coordinate of vector.
in	<i>x</i>	Vector that defined coordinates

**void set ( 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. Consider for instance that we want to initialize the <a href="#">Vect</a> instance with the values $v[i] = \exp(1+x[i])$ ; then, we use this member function as follows <code>v.set("exp("1+x",x);</code>

**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

in	<i>n</i>	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

in	<i>n</i>	Size of vector
in	<i>v</i>	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

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>
----	-----------------	---

**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

in	<i>degree</i>	Polynomial degree of the <a href="#">DG</a> method [Default: 1]
----	---------------	---

**bool isGrid ( ) const**

Say if vector is constructed for a grid.

Vectors constructed for grids are defined with the help of a [Grid](#) instance

Returns

true if vector is constructed with a [Grid](#) instance**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 setIJK ( const string & exp )**

Assign a given function (given by an interpretable algebraic expression) of indices components of vector.

This function enable assigning a value to vector entries as function of indices

Parameters

in	<i>exp</i>	Regular algebraic expression to assign. It must involve the variables i, j and/or k.
----	------------	--

**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>	<a href="#">Mesh</a> instance
in	<i>code</i>	The value is assigned if the node has this code
in	<i>val</i>	Value to assign
in	<i>dof</i>	Degree of freedom to assign [Default: 1]

**void setSideBC ( Mesh & m, int code, T\_ val, size\_t dof = 1 )**

Assign a given value to components of vector corresponding to sides 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
----	----------	------------------

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 setSideBC ( 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 corresponding to sides 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]

Warning

This member function is to be used in the case where a constructor with a [Mesh](#) has been used

**void setSideBC ( 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]

Warning

This member function is to be used in the case where a constructor with a [Mesh](#) has been used

**void setSideBC ( 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]

Warning

This member function is to be used in the case where a constructor with a [Mesh](#) has been used

**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.

Warning

This member function is to be used in the case where a constructor with a [Mesh](#) has been used

**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 (dof) is inserted into vector v 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 (dof) is inserted into vector v 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 (dof) is inserted into vector v which has only one degree of freedom by node or side

Warning

This member function is to be used in the case where a constructor with a [Mesh](#) has been used

**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 Element 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 Side instance
in	<i>b</i>	Local vector to assemble (Instance of class Vect)

**void Assembly ( const Side & *sd*, T\_ \* *b* )**

Assembly of side vector (as C-array) into Vect instance.

Parameters

in	<i>sd</i>	Reference to Side 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<sub>1</sub> approximation. The gradient is then a constant vector for each element.

Parameters

in	<i>v</i>	Vect 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<sub>1</sub> approximation. The gradient is then a constant vector for each element.

Parameters

in	<i>v</i>	Vect 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	<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 ( 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	<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 ( 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	<i>v</i>	<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	<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
----	-----------	----------------------------------

Parameters

in	<i>type</i>	Type of element. This is to be chosen among enumerated values: LINE2, TRIANG3, QUAD4 TETRA4, HEXA8, PENTA6
----	-------------	--

**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 Apxy ( 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)
in	<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

in	<i>i</i>	Rank index in vector (starts at 1)
in	<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

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 add ( size\_t *i*, size\_t *j*, size\_t *k*, T\_ *val* )**

Assign a value to an entry for a 3-index 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)
in	<i>val</i>	Value to assign

**T\_& operator[] ( size\_t *i* )**

Operator [] (Non constant version)

Parameters

in	<i>i</i>	Rank index in vector (starts at 0)
----	----------	------------------------------------

**T\_ operator[] ( size\_t i ) const**

Operator [] (Constant version)

Parameters

in	<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(<a href="#">getNx()</a>, <a href="#">getNy()</a>)</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)
----	----------	---

Parameters

in	$j$	second index in vector (Number of vector components in the y-grid) $v(i, j)$ starts at $v(1, 1)$ to $v(\text{getNx}(), \text{getNy}())$
----	-----	---

**T\_& operator() ( size\_t i, size\_t j, size\_t k )**

Operator () with 3-D indexing (Non constant version).

Parameters

in	$i$	first index in vector (Number of vector components in the x-grid)
in	$j$	second index in vector (Number of vector components in the y-grid)
in	$k$	third index in vector (Number of vector components in the z-grid) $v(i, j, k)$ starts at $v(1, 1, 1)$ to $v(\text{getNx}(), \text{getNy}(), \text{getNz}())$

**T\_ operator() ( size\_t i, size\_t j, size\_t k ) const**

Operator () with 3-D indexing (Constant version).

Parameters

in	$i$	first index in vector (Number of vector components in the x-grid)
in	$j$	second index in vector (Number of vector components in the y-grid)
in	$k$	third index in vector (Number of vector components in the z-grid) $v(i, j, k)$ starts at $v(1, 1, 1)$ to $v(\text{getNx}(), \text{getNy}(), \text{getNz}())$

**Vect<T\_>& operator= ( const VectorX & v )**

Operator = for an instance of VectorX

Parameters

in	$v$	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\_ *vmax*, size\_t *n* )**

Initialize vector entries by setting extremal values and interval.

Parameters

in	<i>vmin</i>	Minimal value to assign to the first entry
in	<i>vmax</i>	Maximal value to assign to the lase entry
in	<i>n</i>	Number of points (including extremities)

Remarks

The vector has a size of n. It is sized in 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>	Vect 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

in	<i>v</i>	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

in	v	<a href="#">Vect</a> instance by which the current instance is multiplied
----	---	---

### **`Vect<complex.t> getFFT ( )`**

Compute FFT transform of vector.

This member function computes the FFT (Fast Fourier Transform) of the vector contained in the instance and returns it

Returns

[Vect<complex<double> >](#) instance containing the FFT

Remarks

The size of [Vect](#) instance must be a power of two and must not exceed the value of  $2^{\text{MAX\_X\_FFT\_SIZE}}$  (This value is set in the header "constants.h")

The [Vect](#) instance can be either a `Vect<double>` or `Vec<complex<double> >`

### **`Vect<complex.t> getInvFFT ( )`**

Compute Inverse FFT transform of vector.

This member function computes the inverse FFT (Fast Fourier Transform) of the vector contained in the instance and returns it

Returns

[Vect<complex<double> >](#) instance containing the FFT

Remarks

The size of [Vect](#) instance must be a power of two and must not exceed the value of  $2^{\text{MAX\_X\_FFT\_SIZE}}$  (This value is set in the header "constants.h")

The [Vect](#) instance can be either a `Vect<double>` or `Vec<complex<double> >`

### **`operator VectorX ( ) const`**

Casting operator.

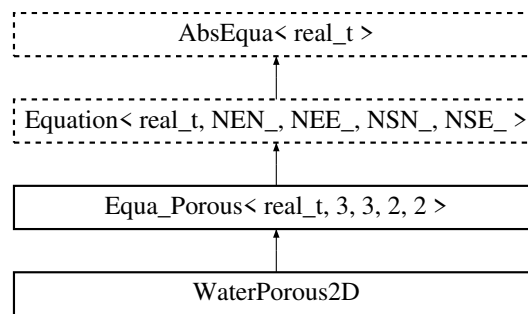
Warning

This constructor is available only if the library `eigen` is used in conjunction with [OFELI](#)

## **7.120 WaterPorous2D Class Reference**

To solve water flow equations in porous media (1-D)

Inheritance diagram for WaterPorous2D:



## Public Member Functions

- [WaterPorous2D](#) ()  
*Default Constructor.*
- [WaterPorous2D](#) ([Mesh](#) &ms, size\_t verb=1)  
*Constructor.*
- [~WaterPorous2D](#) ()  
*Destructor.*
- void [setCoef](#) (real\_t cw, real\_t phi, real\_t rho, real\_t Kx, real\_t Ky, real\_t mu)  
*Set constant coefficients.*
- void [Mass](#) ()  
*Add mass term contribution the element matrix.*
- void [Mobility](#) ()  
*Add mobility term contribution the element matrix.*
- void [BodyRHS](#) (const [Vect](#)< real\_t > &bf, int opt=[GLOBAL\\_ARRAY](#))  
*Add source 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.*
- 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 [run](#) ()  
*Run the equation.*
- void [Mu](#) (const string &exp)  
*Set viscosity given by an algebraic expression.*
- void [updateBC](#) (const [Element](#) &el, const [Vect](#)< real\_t > &bc)  
*Update Right-Hand side by taking into account essential boundary conditions.*
- void [updateBC](#) (const [Vect](#)< real\_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](#)< real\_t > &b)  
*Localize Element Vector from a Vect instance.*
- void [ElementNodeVector](#) (const [Vect](#)< real\_t > &b, [LocalVect](#)< real\_t, NEE\_ > &be)

- Localize Element Vector from a Vect instance.*

  - void [ElementNodeVector](#) (const [Vect](#)< [real.t](#) > &b, [LocalVect](#)< [real.t](#), NEN\_ > &be, int dof)

*Localize Element Vector from a Vect instance.*

  - void [ElementNodeVectorSingleDOF](#) (const [Vect](#)< [real.t](#) > &b, [LocalVect](#)< [real.t](#), NEN\_ > &be)

*Localize Element Vector from a Vect instance.*

  - void [ElementSideVector](#) (const [Vect](#)< [real.t](#) > &b, [LocalVect](#)< [real.t](#), NSE\_ > &be)

*Localize Element Vector from a Vect instance.*

  - void [ElementVector](#) (const [Vect](#)< [real.t](#) > &b, int dof\_type=NODE.FIELD, int flag=0)

*Localize Element Vector.*

  - void [SideVector](#) (const [Vect](#)< [real.t](#) > &b)

*Localize Side Vector.*

  - void [ElementNodeCoordinates](#) ()

*Localize coordinates of element nodes.*

  - void [SideNodeCoordinates](#) ()

*Localize coordinates of side nodes.*

  - void [ElementAssembly](#) ([Matrix](#)< [real.t](#) > \*A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([PETScVect](#)< [real.t](#) > &b)

*Assemble element right-hand side vector into global one.*

  - void [ElementAssembly](#) ([BMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkSMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SkMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([SpMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([TrMatrix](#)< [real.t](#) > &A)

*Assemble element matrix into global one.*

  - void [ElementAssembly](#) ([Vect](#)< [real.t](#) > &v)

*Assemble element vector into global one.*

  - void [SideAssembly](#) ([PETScMatrix](#)< [real.t](#) > &A)

*Assemble side matrix into global one.*

  - void [SideAssembly](#) ([PETScVect](#)< [real.t](#) > &b)

*Assemble side right-hand side vector into global one.*

  - void [SideAssembly](#) ([Matrix](#)< [real.t](#) > \*A)

*Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkSMatrix](#)< [real.t](#) > &A)

*Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SkMatrix](#)< [real.t](#) > &A)

*Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([SpMatrix](#)< [real.t](#) > &A)

*Assemble side (edge or face) matrix into global one.*

  - void [SideAssembly](#) ([Vect](#)< [real.t](#) > &v)

- Assemble side (edge or face) vector into global one.*
  - void [DGElementAssembly](#) ([Matrix](#)< [real.t](#) > \*A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkSMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SkMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([SpMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [DGElementAssembly](#) ([TrMatrix](#)< [real.t](#) > &A)
- Assemble element matrix into global one for the Discontinuous Galerkin approximation.*
  - void [AxbAssembly](#) (const [Element](#) &el, const [Vect](#)< [real.t](#) > &x, [Vect](#)< [real.t](#) > &b)
- Assemble product of element matrix by element vector into global vector.*
  - void [AxbAssembly](#) (const [Side](#) &sd, const [Vect](#)< [real.t](#) > &x, [Vect](#)< [real.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](#)< [real.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](#)< [real.t](#) > & [getLinearSolver](#) ()
- Return reference to linear solver instance.*
  - void [setSolver](#) ([Iteration](#) ls, [Preconditioner](#) pc=IDENT\_PREC)
- Choose solver for the linear system.*
  - void [setMatrixType](#) (int t)
- Choose type of matrix.*
  - int [solveLinearSystem](#) ([Matrix](#)< [real.t](#) > \*A, [Vect](#)< [real.t](#) > &b, [Vect](#)< [real.t](#) > &x)
- Solve the linear system with given matrix and right-hand side.*
  - int [solveLinearSystem](#) ([Vect](#)< [real.t](#) > &b, [Vect](#)< [real.t](#) > &x)
- Solve the linear system with given right-hand side.*

## Public Attributes

- [LocalMatrix](#)< [real.t](#), NEE\_, NEE\_ > [eMat](#)
- LocalMatrix instance containing local matrix associated to current element.*
- [LocalMatrix](#)< [real.t](#), NSE\_, NSE\_ > [sMat](#)
- LocalMatrix instance containing local matrix associated to current side.*
- [LocalVect](#)< [real.t](#), NEE\_ > [ePrev](#)
- LocalVect instance containing local vector associated to current element.*
- [LocalVect](#)< [real.t](#), NEE\_ > [eRHS](#)

*LocalVect instance containing local right-hand side vector associated to current element.*

- [LocalVect](#)< [real\\_t](#), [NEE\\_](#) > [eRes](#)

*LocalVect instance containing local residual vector associated to current element.*

- [LocalVect](#)< [real\\_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.*

### 7.120.1 Detailed Description

To solve water flow equations in porous media (1-D)

To solve water flow equations in porous media (2-D)

Class [WaterPorous2D](#) solves the fluid flow equations of water or any incompressible or slightly compressible fluid in a porous medium in two-dimensional configurations.

Porous media flows are modelled here by the Darcy law. The water, or any other fluid is considered as slightly compressible, i.e., its compressibility coefficient is constant.

Space discretization uses the  $P_1$  (2-Node line) finite element method. Time integration uses class [TimeStepping](#) that provides various well known time integration schemes.

Class [WaterPorous2D](#) solves the fluid flow equations of water or any incompressible or slightly compressible fluid in a porous medium in two-dimensional configurations.

Porous media flows are modelled here by the Darcy law. The water, or any other fluid is considered as slightly compressible, i.e., its compressibility coefficient is constant.

Space discretization uses the  $P_1$  (3-Node triangle) finite element method. Time integration uses class [TimeStepping](#) that provides various well known time integration schemes.

### 7.120.2 Constructor & Destructor Documentation

**WaterPorous2D** ( )

Default Constructor.

Constructs an empty equation.

**WaterPorous2D** ( [Mesh](#) & *ms*, [size\\_t](#) *verb* = 1 )

Constructor.

This constructor uses mesh and reservoir information

Parameters

in	<i>ms</i>	<a href="#">Mesh</a> instance
in	<i>verb</i>	Verbosity parameter

### 7.120.3 Member Function Documentation

**void setCoef ( real\_t cw, real\_t phi, real\_t rho, real\_t Kx, real\_t Ky, real\_t mu )**

Set constant coefficients.

Parameters

in	<i>cw</i>	Compressibility coefficient
in	<i>phi</i>	Porosity
in	<i>rho</i>	Density
in	<i>Kx</i>	x-Absolute permeability
in	<i>Ky</i>	y-Absolute permeability
in	<i>mu</i>	Viscosity

**void BodyRHS ( const Vect< real\_t > &bf, int opt = GLOBAL\_ARRAY )** [virtual]

Add source 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\\_Porous< real\\_t, 3, 3, 2, 2 >](#).

**void BoundaryRHS ( const Vect< real\_t > &sf, int opt = GLOBAL\_ARRAY )** [virtual]

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

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\\_Porous< real\\_t, 3, 3, 2, 2 >](#).

**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. If transient analysis is chosen, 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 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< real\_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< real\_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>• <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>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< real.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 <i>ePrev</i> . This member function is to be used if a constructor with <i>Element</i> was invoked.
----	----------	---

**void ElementNodeVector ( const Vect< real.t > & b, LocalVect< real.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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_t > & b, LocalVect< real_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< real_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< real.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< real\_t > \* A )** [inherited]

Assemble element matrix into global one.

Parameters

<i>A</i>	Pointer to global matrix (abstract class: can be any of classes <code>SkSMatrix</code> , <code>SkMatrix</code> , <code>SpMatrix</code> )
----------	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( PETScMatrix< real\_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< real\_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< real\_t > & A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as a BMatrix instance
-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkSMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

$A$	Global matrix stored as an SkSMatrix instance
-----	---

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SkMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SkMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( SpMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void ElementAssembly ( TrMatrix< real.t > &A )** [inherited]

Assemble element matrix into global one.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable theElement

**void ElementAssembly ( Vect< real.t > &  $v$  )** [inherited]

Assemble element vector into global one.

Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

Warning

The element pointer is given by the global variable theElement

**void SideAssembly ( PETScMatrix< real.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< real.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< real.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 SkSMatrix, SkMatrix, SpMatrix)
----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkSMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkSMatrix instance
----	----------	---

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SkMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SkMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( SpMatrix< real.t > & *A* )** [inherited]

Assemble side (edge or face) matrix into global one.

## Parameters

in	<i>A</i>	Global matrix stored as an SpMatrix instance
----	----------	--

## Warning

The side pointer is given by the global variable `theSide`

**void SideAssembly ( Vect< real.t > & *v* )** [inherited]

Assemble side (edge or face) vector into global one.

Parameters

in	$v$	Global vector (Vect instance)
----	-----	-------------------------------

Warning

The side pointer is given by the global variable `theSide`

**void DGElementAssembly ( Matrix< real.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 SkSMatrix, SkMatrix, SpMatrix)
---	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkSMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

A	Global matrix stored as an SkSMatrix instance
---	---

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SkMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	A	Global matrix stored as an SkMatrix instance
----	---	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( SpMatrix< real.t > & A )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an SpMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void DGElementAssembly ( TrMatrix< real.t > &  $A$  )** [inherited]

Assemble element matrix into global one for the Discontinuous Galerkin approximation.

Parameters

in	$A$	Global matrix stored as an TrMatrix instance
----	-----	--

Warning

The element pointer is given by the global variable `theElement`

**void AxbAssembly ( const Element &  $el$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of element matrix by element vector into global vector.

Parameters

in	$el$	Reference to Element instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector to add (Vect instance)

**void AxbAssembly ( const Side &  $sd$ , const Vect< real.t > &  $x$ , Vect< real.t > &  $b$  )**  
[inherited]

Assemble product of side matrix by side vector into global vector.

Parameters

in	$sd$	Reference to Side instance
in	$x$	Global vector to multiply by (Vect instance)
out	$b$	Global vector (Vect 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>

**void setMatrixType ( int *t* )** [inherited]

Choose type of matrix.

Parameters

in	<i>t</i>	Type of the used matrix. To choose among the enumerated values: SKYLINE, SPARSE, DIAGONAL TRIDIAGONAL, SYMMETRIC, UNSYMMETRIC, IDENTITY
----	----------	---

**int solveLinearSystem ( Matrix< real.t > \* *A*, Vect< real.t > & *b*, Vect< real.t > & *x* )**  
[inherited]

Solve the linear system with given matrix and right-hand side.

Parameters

in	<i>A</i>	Pointer to matrix of the system
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

**int solveLinearSystem ( Vect< real.t > & *b*, Vect< real.t > & *x* )** [inherited]

Solve the linear system with given right-hand side.

Parameters

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

#### 7.120.4 Member Data Documentation

**LocalVect<real.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

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