OFELI

An Object Oriented Finite Element Library

Reference Guide

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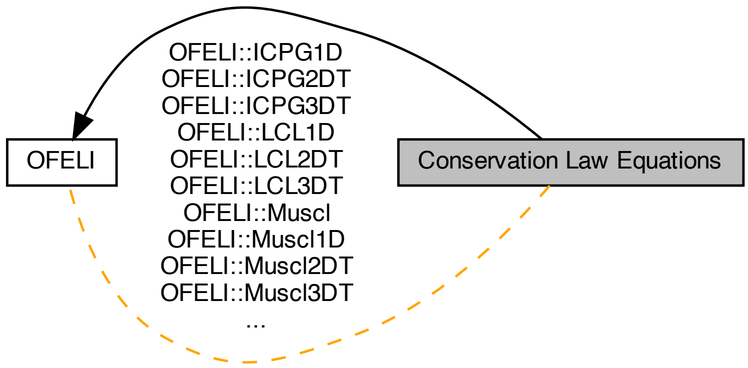
5.1 Conservation Law Equations

Conservation law equations.

Collaboration diagram for 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.

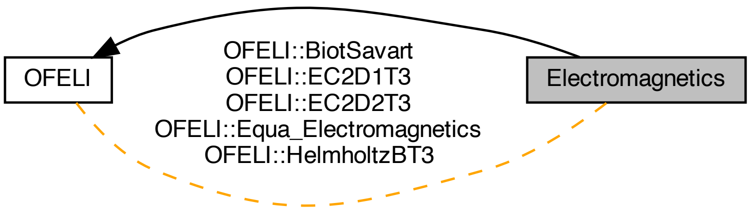
5.1.1 Detailed Description

Conservation law equations.

5.2 Electromagnetics

Electromagnetic equations.

Collaboration diagram for Electromagnetics:



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< 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.

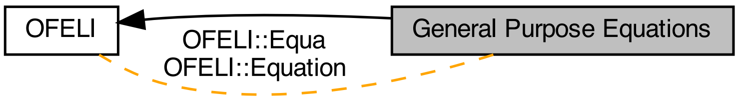
5.2.1 Detailed Description

Electromagnetic equations.

5.3 General Purpose Equations

Gathers equation related classes.

Collaboration diagram for General Purpose Equations:



Classes

- class Equa

  Mother abstract class to describe equation.
- class Equation< 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.

5.3.1 Detailed Description

Gathers equation related classes.

5.3.2 Function Documentation

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

Assemble local vector into global vector.

Parameters

in	*e*	Reference to local entity (Element or Side)
in	*be*	Local vector
in,out	*b*	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	*e*	Reference to local entity (Element or Side)

in	*ae*	Local matrix
in,out	*b*	Global vector

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

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

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

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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 Element
in	*ae*	Local matrix
in,out	*A*	Global matrix

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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 Element
in	*ae*	Local matrix
in,out	*A*	Global matrix

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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 Element
in	*be*	Local vector
in,out	*b*	Global vector

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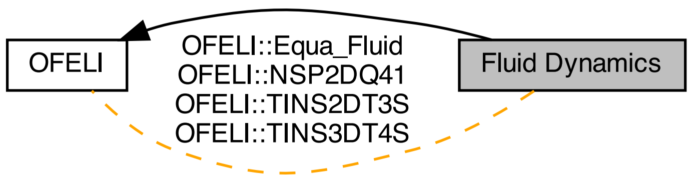
5.4 Fluid Dynamics

Fluid Dynamics equations.

Collaboration diagram for Fluid Dynamics:



Classes

- class Equa_Fluid< 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 penaly 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 tatrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

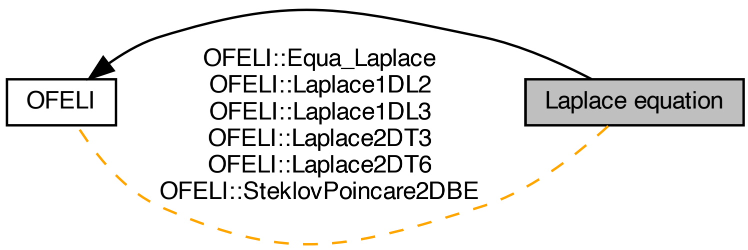
5.4.1 Detailed Description

Fluid Dynamics equations.

5.5 Laplace equation

Laplace and Poisson equations.

Collaboration diagram for Laplace equation:



Classes

- class Equa_Laplace< 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 Laplace2DT3

  To build element equation for the Laplace equation using the 2-D triangle element (P_1).
- class Laplace2DT6

  To build element equation for the Laplace equation using the 2-D triangle element (P_2).
- 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 piecewie constant boundary elemen.

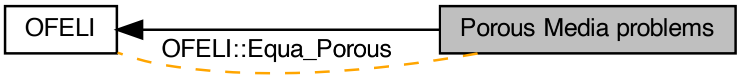
5.5.1 Detailed Description

Laplace and Poisson equations.

5.6 Porous Media problems

Porous Media equation classes.

Collaboration diagram for Porous Media problems:



Classes

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

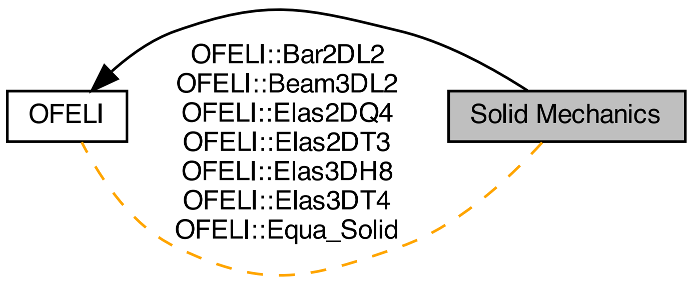
5.6.1 Detailed Description

Porous Media equation classes.

5.7 Solid Mechanics

Solid Mechanics finite element equations.

Collaboration diagram for Solid Mechanics:



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< NEN_, NEE_, NSN_, NSE_ >

  Abstract class for Solid Mechanics Finite Element classes.

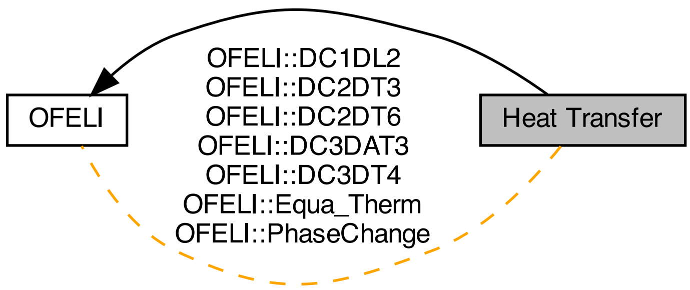
5.7.1 Detailed Description

Solid Mechanics finite element equations.

5.8 Heat Transfer

Heat Transfer equations.

Collaboration diagram for Heat Transfer:



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< NEN_, NEE_, NSN_, NSE_ >

  Abstract class for Heat transfer Finite Element classes.
- class PhaseChange

  This class enables defining phase change laws for a given material.

5.8.1 Detailed Description

Heat Transfer equations.

5.9 Input/Output

Input/Output utility classes.

Collaboration diagram for Input/Output:

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.

5.9.1 Detailed Description

Input/Output utility classes.

5.9.2 Macro Definition Documentation

#define MAX_NB_PAR 50

Maximum number of parameters.

Used in class IPF

#define MAX_ARRAY_SIZE 100

Maximum array size.
Used in class IPF

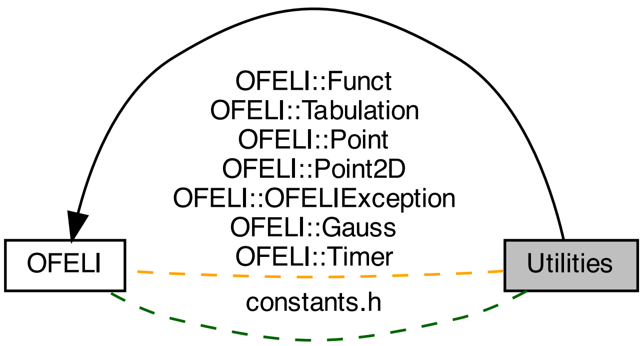
#define MAX_INPUT_STRING_LENGTH 100

Maximum string length.
Used in class IPF

5.10 Utilities

Utility functions and classes.

Collaboration diagram for Utilities:



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 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 0.333333333333333333333333333333
- #define OFELI_SIXTH 0.166666666666666666666666666667
- #define OFELI_TWELVETH 0.083333333333333333333333333333
- #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 VLG 1.e10
- #define OFELI_IMAG std::complex<double>(0.,1.);
- #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::list< T_ > &l)

  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 (const Vect< real_t > &v, const Mesh &mesh, string output_file, int opt)

  Save a 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, int f=1)

  Save a vector to an input `Gnuplot` *file.*

- void saveGnuplot (Mesh &mesh, string input_file, string output_file, int f=1)

  Save a vector to an input `Gnuplot` *file.*
- void saveTecplot (string input_file, string output_file, string mesh_file, int f=1)

  Save a vector to an output file to an input `Tecplot` *file.*
- void saveTecplot (Mesh &mesh, string input_file, string output_file, int f=1)

  Save a vector to an output file to an input `Tecplot` *file.*
- void saveVTK (string input_file, string output_file, string mesh_file, int f=1)

  Save a vector to an output `VTK` *file.*
- void saveVTK (Mesh &mesh, string input_file, string output_file, int f=1)

  Save a vector to an output `VTK` *file.*
- void saveGmsh (string input_file, string output_file, string mesh_file, int f=1)

  Save a vector to an output `Gmsh` *file.*
- void saveGmsh (Mesh &mesh, string input_file, string output_file, int f=1)

  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< real_t > &a, const Point< real_t > &b, real_t toler=OFELI_TOLERANCE)

  Return `true` if both instances of class Point<double> are distant with less then `toler`

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

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

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

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

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

  Comparison operator. Returns true if all components of first vector are lower than those of second one.

- 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.
- real_t Discrepancy (Vect< real_t > &x, const Vect< real_t > &y, int n, int type=1)

  Return discrepancy between 2 vectors `x` and `y`
- real_t Discrepancy (Vect< complex_t > &x, const Vect< complex_t > &y, int n, int type=1)

  Return discrepancy between 2 vectors `x` and `y`
- 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 Kronecker (int i, int j)

  Return Kronecker delta of `i` and `j`.

- 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)

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

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

  Mutiply 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 Axpy (size_t n, T_ a, T_ *x, T_ *y)

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

  Multiply vector `x` *by* `a` *and add result to* `y`
- template<class T_ >
  void Axpy (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.

- 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.

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

  Function to convert a string to a template type parameter.

5.10.1 Detailed Description

Utility functions and classes.

5.10.2 Macro Definition Documentation

#define OFELI_E 2.71828182845904523536028747135

Value of *e* or *exp* (with 28 digits)

#define OFELI_PI 3.14159265358979323846264338328

Value of *Pi* (with 28 digits)

#define OFELI_THIRD 0.333333333333333333333333333333

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

#define OFELI_SIXTH 0.16666666666666666666666666667

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

#define OFELI_TWELVETH 0.08333333333333333333333333333

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 VLG 1.e10

Very large number: A real number for penalty

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

= Unit imaginary number (`i`)

#define CATCH_EXCEPTION

Value:

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

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

5.10.3 Function Documentation

ostream & operator<< (ostream & *s*, const complex_t & *x*)

Output a complex number.

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Rachid Touzani

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

Output a string.

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Rachid Touzani

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ostream & operator<< (ostream & *s*, const vector< T_ > & *v*)

Output a vector instance.

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Rachid Touzani

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ostream & operator<< (ostream & *s*, const std::list< T_ > & *l*)

Output a vector instance.

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Rachid Touzani

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ostream & operator<< (ostream & *s*, const std::pair< T_, T_ > & *a*)

Output a pair instance.

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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	*v*	Vect instance to save
in	*output_file*	Output file where to save the vector
in	*opt*	Option to choose file format to save. This is to be chosen among enumerated values: GMSH GNUPLOT MATLAB TECPLOT V↩ TK

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Rachid Touzani

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void saveField (const Vect< real_t > & *v*, const Mesh & *mesh*, string *output_file*, int *opt*)

Save a vector to an output file in a given file format.
Case where the vector does not contain mesh information

Parameters

in	*v*	Vect instance to save
in	*mesh*	Mesh instance
in	*output_file*	Output file where to save the vector
in	*opt*	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	*v*	Vect instance to save
in	*g*	Grid instance
in	*output_file*	Output file where to save the vector
in	*opt*	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*, int *f* = 1)

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	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (gnuplot format file)
in	*mesh_file*	File containing mesh data
in	*f*	Field is stored each `f` time step [Default: `1`

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Rachid Touzani

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void saveGnuplot (Mesh & *mesh*, string *input_file*, string *output_file*, int *f* = 1)

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	*mesh*	Reference to Mesh instance
in	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (gnuplot format file)
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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void saveTecplot (string *input_file*, string *output_file*, string *mesh_file*, int *f* = 1)

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	*input_file*	Input file (OFELI XML file containing a field).

in	*output_file*	Output file (gnuplot format file)
in	*mesh_file*	File containing mesh data
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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void saveTecplot (Mesh & *mesh*, string *input_file*, string *output_file*, int *f* = *1*)

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	*mesh*	Reference to Mesh instance
in	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (gnuplot format file)
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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saveVTK (string *input_file*, string *output_file*, string *mesh_file*, int *f* = *1*)

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	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (VTK format file)
in	*mesh_file*	File containing mesh data
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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saveVTK (Mesh & ***mesh*****, string** ***input_file*****, string** ***output_file*****, int** ***f*** **=** *1* **)**

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	*mesh*	Reference to Mesh instance
in	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (VTK format file)
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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void saveGmsh (string *input_file*, string *output_file*, string *mesh_file*, int *f* = *1*)

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	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (Gmsh format file)
in	*mesh_file*	File containing mesh data
in	*f*	Field is stored each `f` time step [Default: `1`]

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Rachid Touzani

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void saveGmsh (Mesh & *mesh*, string *input_file*, string *output_file*, int *f* = *1*)

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	*mesh*	Reference to Mesh instance
in	*input_file*	Input file (OFELI XML file containing a field).
in	*output_file*	Output file (Gmsh format file)
in	*f*	Field is stored each `f` time step [Default: `1`]

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

Operator ==
Return `true` if `a=b`, `false` if not.

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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`

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Rachid Touzani

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

Operator +
Translate `a` by `x`

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Rachid Touzani

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

Unary Operator -
Return minus `a`

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

Operator -
Return point a minus point b

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

Operator -
Translate a by -x

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Rachid Touzani

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

Operator *
Return point b premultiplied by constant a

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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

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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

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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

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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< real_t > & *a*, const Point< real_t > & *b*, real_t *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< real_t > & *a*, const Point< real_t > & *b*)

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

Author

Rachid Touzani

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

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

Author

Rachid Touzani

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

Comparison operator. Returns true if all components of first vector are lower than those of second one.

Return minus `a`

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Rachid Touzani

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ostream & operator<< (std::ostream & *s*, const Point< T_ > & *a*)

Output point coordinates.

Author

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

Operator ==.
Return `true` if `a=b`, false if not.

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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`

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

Unary Operator -
Return minus `a`

Author

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

Operator -
Return point `a` minus point `b`

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Rachid Touzani

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

Operator -
Translate `a` by `-x`

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

Operator $*$.
Return point `b` premultiplied by constant `a`

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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`

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Rachid Touzani

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

Operator $*$
Return point `b` postmultiplied by constant `a`

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

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

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

Operator /
Return point `b` divided by constant `a`

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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

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real_t Discrepancy (Vect< real_t > & *x*, const Vect< real_t > & *y*, int *n*, int *type* = *1*)

Return discrepancy between 2 vectors `x` and `y`

Parameters

`in,out`	*x*	First vector (Instance of class Vect). On output, `x` is assigned the vector `y`
`in`	*y*	Second vector (Instance of class Vect)
`in`	*n*	Type of norm • 1: Weighted 1-Norm • 2: Weighted 2-Norm • 0: Max-Norm
`in`	*type*	Discrepancy type (0: Absolute, 1: Relative [Default])

Returns

Computed discrepancy value

real_t Discrepancy (Vect< complex_t > & *x*, const Vect< complex_t > & *y*, int *n*, int *type* = *1*)

Return discrepancy between 2 vectors x and y

Parameters

in,out	*x*	First vector (Instance of class Vect). On output, x is assigned the vector y
in	*y*	Second vector (Instance of class Vect)
in	*n*	Type of norm • 1: Weighted 1-Norm • 2: Weighted 2-Norm • 0: Max-Norm
in	*type*	Discrepancy type (0: Absolute, 1: Relative [Default])

Returns

Computed discrepancy value

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	*file*	Input mesh file name.
in	*form*	Format of the mesh file. This one can be chosen among the enumerated values: • `GMSH`: Mesh generator **Gmsh**, see site: `http://www.geuz.org/gmsh/` • `MATLAB`: Matlab file, see site: `http://www.mathworks.com/products/matlab/` • `EASYMESH`: **Easymesh** is a 2-D mesh generator, see site: `http://web.mit.edu/easymesh_v1.4/www/easymesh.html` • `GAMBIT`: **Gambit** is a mesh generator associated to **Fluent** `http://www.stanford.edu/class/me469b/gambit_download.html` • `BAMG`: Mesh generator `Bamg`, see site: `http://raweb.inria.fr/rapportsactivite/RA2002/gamma/uid25.html` • `NETGEN`: **Netgen** is a 3-D mesh generator, see site: `http://www.hpfem.jku.at/netgen/` • `TETGEN`: **Tetgen** is a 3-D mesh generator, see site: `http://tetgen.berlios.de/` • `TRIANGLE_FF`: **Triangle** is a 2-D mesh generator, see site: `http://www.cs.cmu.edu/~quake/triangle.html`
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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 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	*file*	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	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	Name of a file (without extension) written in **Easymesh** format. Actually, the function Easymesh2MDF attempts to read mesh data from files `file.e`, `file.n` and `file.s` produced by **Easymesh**.

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	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	Name of a file written in the **Gambit** neutral format.
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	Name of a file written in the **Gmsh** format.
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	Name of a file created by Matlab by executing the script file `Matlab2OFELI.m`
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	Name of a file written in the Netgen format.
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	Number of degrees of freedom for each node. This information is not provided, in general, by mesh generators. [default = 1]

Author

Rachid Touzani

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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	*file*	Name of a file written in the **Tetgen** format.
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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/`

Parameters

in	*file*	Name of a file written in the **Tetgen** format.
out	*mesh*	Mesh instance created by the function.
in	*nb_dof*	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	*file*	File where to store mesh
in	*mesh*	Mesh instance to save
in	*form*	Format of the mesh file. This one can be chosen among the enumerated values: • `GMSH`: Mesh generator and graphical postprocessor **Gmsh:** `http://www.geuz.org/gmsh/` • `GNUPLOT`: Well known graphics software: `http://www.gnuplot.info/` • `MATLAB`: Matlab file: `http://www.mathworks.com/products/matlab/` • `TECPLOT`: Commercial graphics software: `http://www.tecplot.com` • `VTK`: Graphics format for the free postprocessor **ParaView:** `http://public.kitware.com/VTK/`

Author

Rachid Touzani

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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	*file*	Output file in **Gmsh** format.
in	*mesh*	Mesh instance to save.

Author

Rachid Touzani

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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	*file*	Output file in **Gnuplot** format.
in	*mesh*	Mesh instance to save.

Author

Rachid Touzani

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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	*file*	Output file in **Matlab** format.
in	*mesh*	Mesh 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	*file*	Output file in **Tecplot** format.
in	*mesh*	Mesh instance to save.

Author

Rachid Touzani

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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	*file*	Output file in **VTK** format.
in	*mesh*	Mesh instance to save.

Author

Rachid Touzani

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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	*file*	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	*mesh*	Mesh 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`) in 1994.

Parameters

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

Note

Condition: `n+2>t` (No curve results if `n+2<=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	*prog*	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`	*a*	Vector to sort.
`in`	*begin*	index of starting iterator
`in`	*end*	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`	*a*	Vector to sort.
`in`	*begin*	index of starting index (default value is 0)
`in`	*end*	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`	*a*	Vector to sort.
`in`	*begin*	index of starting index (0 for the beginning of the vector)
`in`	*end*	index of ending index
`in`	*compare*	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

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

Mutiply 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*)

Mutiply 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*)

Mutiply 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 Axpy (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 Axpy (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 Axpy (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>

void clear (vector< T_ > & *v*)

Assign `0` to all entries of a vector.
Parameters

in	*v*	Vector to clear

void clear (Vect< T_ > & *v*)

Assign `0` to all entries of a vector.

Parameters

in	v	Vector to clear

real_t Nrm2 (size_t *n*, real_t * *x*)

Return 2-norm of array `x`
Parameters

in	n	is Array length
in	x	Array to treat

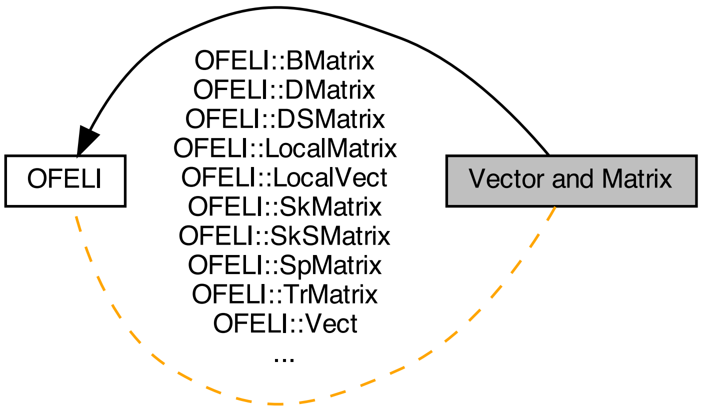
bool Equal (real_t *x*, real_t *y*, real_t *toler* = OFELI_EPSMCH)

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

5.11 Vector and Matrix

Vector and matrix classes.

Collaboration diagram for Vector and Matrix:



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 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.

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_>
  LocalVect< T_, NR_ > operator* (const LocalMatrix< T_, NR_, NC_ > &A, const LocalVect< T_, NC_ > &x)

  *Operator * (Multiply matrix `A` by vector `x`)*
- 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 Axpy (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_ >
  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.
- template<class T_ >
Vect< T_ > operator+ (const Vect< T_ > &x, const Vect< T_ > &y)
  Operator + (Addition of two instances of class Vect)
- template<class T_ >
Vect< T_ > operator- (const Vect< T_ > &x, const Vect< T_ > &y)
  Operator - (Difference between two vectors of class Vect)
- template<class T_ >
Vect< T_ > operator* (const T_ &a, const Vect< T_ > &x)
  *Operator * (Premultiplication of vector by constant)*
- template<class T_ >
Vect< T_ > operator* (const Vect< T_ > &x, const T_ &a)
  *Operator * (Postmultiplication of vector by constant)*
- template<class T_ >
Vect< T_ > operator/ (const Vect< T_ > &x, const T_ &a)
  Operator / (Divide vector entries by constant)
- template<class T_ >
T_ Dot (const Vect< T_ > &x, const Vect< T_ > &y)
  Calculate dot product of two vectors.
- void Modulus (const Vect< complex_t > &x, Vect< real_t > &y)
  Calculate modulus of complex vector.
- void Real (const Vect< complex_t > &x, Vect< real_t > &y)
  Calculate real part of complex vector.
- void Imag (const Vect< complex_t > &x, Vect< real_t > &y)
  Calculate imaginary part of complex vector.
- template<class T_ >
istream & operator>> (istream &s, Vect< T_ > &v)
- template<class T_ >
ostream & operator<< (ostream &s, const Vect< T_ > &v)
  Output vector in output stream.
- real_t operator* (const vector< real_t > &x, const vector< real_t > &y)
  *Operator * (Dot product of 2 vector instances)*

Friends

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

5.11.1 Detailed Description

Vector and matrix classes.

5.11.2 Function Documentation

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

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

Parameters

in	*A*	BMatrix instance to multiply by vector
in	*b*	Vect 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	*A*	DMatrix instance to multiply by vector
in	*b*	Vect 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*	DSMatrix instance to multiply by vector
in	*b*	Vect 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`

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

Operator * (Multiply matrix `A` by vector `x`)

This function performs a matrix-vector product and returns resulting vector as a reference to LocalVect instance

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

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

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

Parameters

in	*A*	SkMatrix instance to multiply by vector
in	*b*	Vect 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.

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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*	SkSMatrix instance to multiply by vector
in	*b*	Vect 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*	SpMatrix instance to multiply by vector
in	*b*	Vect 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.

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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	*A*	TrMatrix instance to multiply by vector
in	*b*	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.

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Vect< T_ > operator+ (const Vect< T_ > & *x*, const Vect< T_ > & *y*)

Operator + (Addition of two instances of class Vect)

Returns

x + y

Vect< T_ > operator- (const Vect< T_ > & *x*, const Vect< T_ > & *y*)

Operator - (Difference between two vectors of class Vect)

Returns

x - y

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

Operator * (Premultiplication of vector by constant)

Returns

a*x

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

Operator * (Postmultiplication of vector by constant)

Returns

x*a

Vect< T_ > operator/ (const Vect< T_ > & *x*, const T_ & *a*)

Operator / (Divide vector entries by constant)

Returns

x/a

T_ Dot (const Vect< T_ > & *x*, const Vect< T_ > & *y*)

Calculate dot product of two vectors.

Returns

Dot (inner or scalar) product Calculate dot (scalar) product of two vectors

void Modulus (const Vect< complex_t > & *x*, Vect< real_t > & *y*)

Calculate modulus of complex vector.

Parameters

in	x	Vector with complex value entries
out	y	Vector containing moduli of entries of x

void Real (const Vect< complex_t > & *x*, Vect< real_t > & *y*)

Calculate real part of complex vector.
Parameters

in	x	Vector with complex value entries
out	y	Vector containing real parts of entries of x

void Imag (const Vect< complex_t > & *x*, Vect< real_t > & *y*)

Calculate imaginary part of complex vector.
Parameters

in	x	Vector with complex value entries
out	y	Vector containing imaginary parts of entries of x

istream & operator>> (istream & *s*, Vect< T_ > & *a*)

Read vector from input stream

ostream & operator<< (ostream & *s*, const Vect< T_ > & *v*)

Output vector in output stream.
Level of vector output depends on the global variable `Verbosity`

- If Verbosity=0, this function outputs vector size only.
- If Verbosity>0, this function outputs vector size, vector name, value of time, and number of components
- If Verbosity>1, this function outputs in addition the first 10 entries in vector
- If Verbosity>2, this function outputs in addition the first 50 entries in vector
- If Verbosity>3, this function outputs in addition the first 100 entries in vector
- If Verbosity>4, this function outputs all vector entries

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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.y`

5.11.3 Friends

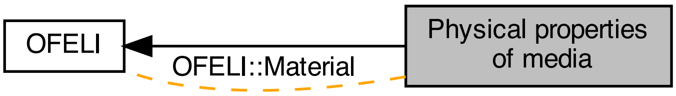
ostream & operator<< (ostream & *s*, const SpMatrix< TT_ > & *A*) `[friend]`

Output matrix in output stream

5.12 Physical properties of media

Physical properties of materials and media.

Collaboration diagram for Physical properties of 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.

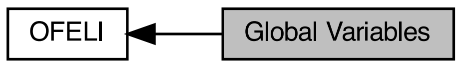
5.12.1 Detailed Description

Physical properties of materials and media.

5.13 Global Variables

All global variables in the library.

Collaboration diagram for Global Variables:



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 Verbosity

  Verbosity parameter.
- int theStep

  Time step counter.
- int theIteration

  Iteration counter.
- int NbTimeSteps

  Number of time steps.
- int MaxNbIterations

  Maximal number of iterations.
- real_t theTimeStep

  Time step label.
- real_t theTime

  Time value.
- real_t theFinalTime

  Final time value.
- real_t theTolerance

  Tolerance value for convergence.
- real_t theDiscrepancy

  Value of discrepancy for an iterative procedure Its default value is `1.0`.
- bool Converged

  Boolean variable to say if an iterative procedure has converged.
- bool InitPetsc

5.13.1 Detailed Description

All global variables in the library.

5.13.2 Variable Documentation

Node$*$ theNode

A pointer to Node.
Useful for loops on nodes

Element$*$ theElement

A pointer to Element.
Useful for loops on elements

Side$*$ theSide

A pointer to Side.
Useful for loops on sides

Edge$*$ theEdge

A pointer to Edge.
Useful for loops on edges

int Verbosity

Verbosity parameter.
Parameter for verbosity of message outputting.
The value of Verbosity can be modified anywhere in the calling programs. It allows outputting messages in function of the used class or function. To see how this parameter is used in any class, the OFELI user has to read corresponding documentation.
Its default value is 1

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

real_t theTimeStep

Time step label.

Remarks

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

real_t theTime

Time value.

Remarks

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

real_t theFinalTime

Final time value.

Remarks

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

real_t theTolerance

Tolerance value for convergence.

Remarks

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

bool Converged

Boolean variable to say if an iterative procedure has converged.
Its default value is `false`

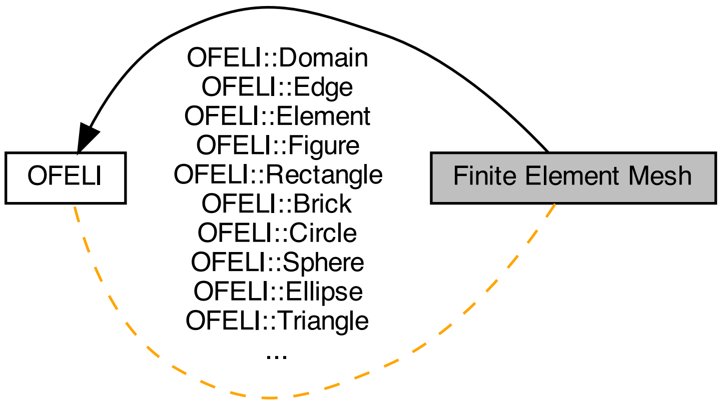
bool InitPetsc

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

5.14 Finite Element Mesh

Mesh management classes

Collaboration diagram for Finite Element Mesh:



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 ElementLoop(m) for ((m).topElement(); (theElement=(m).getElement());)
- #define ActiveElementLoop(m) for ((m).topElement(); (theElement=(m).getActiveElement());)
- #define SideLoop(m) for ((m).topSide(); (theSide=(m).getSide());)
- #define EdgeLoop(m) for ((m).topEdge(); (theEdge=(m).getEdge());)
- #define NodeLoop(m) for ((m).topNode(); (theNode=(m).getNode());)
- #define BoundaryNodeLoop(m) for ((m).topBoundaryNode(); (theNode=(m).getBoundary←
  Node());)
- #define BoundarySideLoop(m) for ((m).topBoundarySide(); (theSide=(m).getBoundary←
  Side());)
- #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 rate=0.2)

  Calculate deformed mesh using a displacement field.
- 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 (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 getMaxElementMeasure (const Mesh &m)

  Return maximal 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.
- int NodeInElement (const Node *nd, const Element *el)

  Say if a given node belongs to a given element.
- int NodeInSide (const Node *nd, const Side *sd)

  Say if a given node belongs to a given side.
- int SideInElement (const Side *sd, const Element *el)

  Say if a given side belongs to a given element.
- ostream & operator<< (ostream &s, const Node &nd)

  Output node data.
- ostream & operator<< (ostream &s, const Side &sd)

  Output side data.

5.14.1 Detailed Description

Mesh management classes

5.14.2 Macro Definition Documentation

#define GRAPH_MEMORY 1000000

Memory necessary to store matrix graph.
This value is necessary only if nodes are to be renumbered.

#define 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 ElementLoop(*m*) for ((m).topElement(); (theElement=(m).getElement());)

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

Note

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

#define ActiveElementLoop(*m*) for ((m).topElement(); (theElement=(m).getActive←Element());)

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

Note

: Each iteration updates the pointer `theElement` to current Element
: This macro is necessary only if adaptive meshing is used

#define SideLoop(*m*) for ((m).topSide(); (theSide=(m).getSide());)

A macro to loop on mesh sides *m* : Instance of Mesh

Note

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

#define EdgeLoop(*m*) for ((m).topEdge(); (theEdge=(m).getEdge());)

A macro to loop on mesh edges *m* : Instance of Mesh

Note

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

#define NodeLoop(*m*) for ((m).topNode(); (theNode=(m).getNode());)

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

Note

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

#define BoundaryNodeLoop(*m*) for ((m).topBoundaryNode(); (theNode=(m).getBoundaryNode());)

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

Note

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

#define BoundarySideLoop(*m*) for ((m).topBoundarySide(); (theSide=(m).getBoundary↩ Side());)

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

Note

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

#define theNodeLabel theNode->n()

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

5.14.3 Function Documentation

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

Function to define a Figure instance as the intersection of two Figure instances.
Parameters

`in`	*f1*	First Figure instance
`in`	*f2*	Second Figure 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`	*f1*	First Figure instance
`in`	*f2*	Second Figure instance

Returns

Updated resulting Figure instance

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

Function to define a Figure instance as the set subtraction of two Figure instances.
Parameters

`in`	*f1*	First Figure instance to subtract from
`in`	*f2*	Second Figure instance to subtract

Returns

Updated resulting Figure instance

ostream & operator<< (ostream & *s*, const Mesh & *ms*)

Output mesh data.

Level of mesh output depends on the global variable `Verbosity`

- If Verbosity=0 or Verbosity=1, this function outputs only principal mesh parameters: number of nodes, number of elements, ...
- If Verbosity>1, this function outputs in addition the list of 10 first nodes, elements and sides
- If Verbosity>2, this function outputs in addition the list of 50 first nodes, elements and sides
- If Verbosity>3, this function outputs all mesh data

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

Output NodeList instance.

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Rachid Touzani

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

Output ElementList instance.

Author

Rachid Touzani

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

Output SideList instance.

Author

Rachid Touzani

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

Output EdgeList instance.

Author

Rachid Touzani

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size_t Label (const Node & *nd*)

Return label of a given node.

Parameters

in	*nd*	Reference to Node instance

Returns

Label of node

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size_t Label (const Element & *el*)

Return label of a given element.
Parameters

in	*el*	Reference to Element instance

Returns

Label of element

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size_t Label (const Side & *sd*)

Return label of a given side.
Parameters

in	*sd*	Reference to Side instance

Returns

Label of side

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size_t Label (const Edge & *ed*)

Return label of a given edge.

Parameters

in	*ed*	Reference to Edge instance

Returns

Label of edge

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size_t NodeLabel (const Element & *el*, size_t *n*)

Return global label of node local label in element.

Parameters

in	*el*	Reference to Element instance
in	*n*	Local label of node in element

Returns

Global label of node

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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	*sd*	Reference to Side instance
in	*n*	Local label of node in side

Returns

Global label of node

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Rachid Touzani

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Point< real_t > Coord (const Node & *nd*)

Return coordinates of a given node.

Parameters

in	*nd*	Reference to Node instance

Returns

Coordinates of node

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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	*nd*	Reference to Node instance
in	*i*	Label of dof [Default: 1]

Returns

Code of dof of node

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Rachid Touzani

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int Code (const Element & *el*)

Return code of a given element.
Parameters

in	*el*	Reference to Element instance

Returns

Code of element

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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	*sd*	Reference to Side instance
in	*i*	Label of dof [Default: 1]

Returns

Code of dof of side

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

Check equality between 2 elements.
Parameters

in	*el1*	Reference to first Side instance
in	*el2*	Reference to second Side 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	*sd1*	Reference to first Side instance
in	*sd2*	Reference to second Side 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* = `0.2`)

Calculate deformed mesh using a displacement field.

Parameters

in,out	*mesh*	Mesh instance. On output, node coordinates are modified to take into account the displacement
in	*u*	Displacement field at nodes
in	*a*	Maximal deformation rate. [Default: 1]. A typical value is 0.2 (*i.e.* 20%).

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

Note

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

Author

Rachid Touzani

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void MeshToMesh (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	*u1*	Input vector of nodal values defined on first mesh. This vector instance must contain Mesh instance
out	*u2*	Output vector of nodal values defined on second mesh. This vector instance must contain Mesh instance
in	*nx*	Number of cells in the x-direction in the fine structured grid
in	*ny*	Number of cells in the y-direction in the fine structured grid The default value of `ny` is `0`, i.e. a 1-D grid
in	*nz*	Number of cells in the z-direction in the fine structured grid The default value of `nz` is `0`, i.e. a 1-D or 2-D grid
in	*dof*	Label of degree of freedom of vector `u`. Only this dof is considered. [Default: `1`]

Note

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

Author

Rachid Touzani

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

Note

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

Author

Rachid Touzani

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real_t getMaxSize (const Mesh & *m*)

Return maximal size of element edges for given mesh.
Parameters

`in`	*m*	Reference to mesh instance

Author

Rachid Touzani

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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

Author

Rachid Touzani

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real_t getMinElementMeasure (const Mesh & *m*)

Return minimal 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 getMaxElementMeasure (const Mesh & *m*)

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

Author

Rachid Touzani

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

Author

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	*nd*	Pointer to Node
in	*el*	Pointer to Element

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	*nd*	Pointer to Node
in	*sd*	Pointer to Side

Returns

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

Author

Rachid Touzani

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

Say if a given side belongs to a given element.
Parameters

in	*sd*	Pointer to Side
in	*el*	Pointer to Element

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

Rachid Touzani

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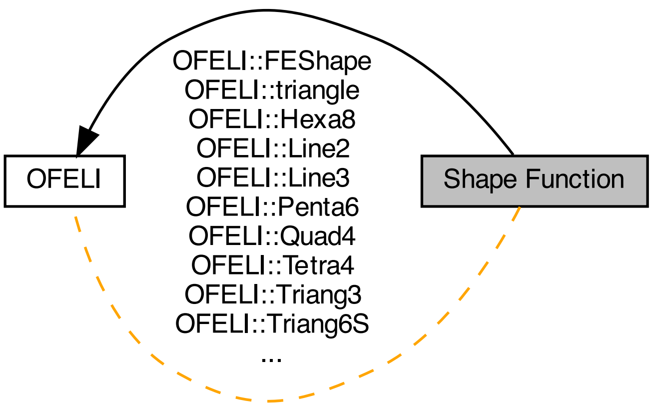
5.15 Shape Function

Shape function classes.

Collaboration diagram for Shape Function:



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 Q1-isoparametric interpolation.

- class Line2

  To describe a 2-Node planar line finite element.

- class Line3

  To describe a 3-Node quadratic planar line finite element.

- class Penta6

  Defines a 6-node pentahedral finite element using P_1 interpolation in local coordinates `(s.x,s.y)` *and Q_1 isoparametric interpolation in local coordinates* `(s.x,s.z)` *and* `(s.y,s.z)`*.*

- class Quad4

  Defines a 4-node quadrilateral finite element using Q_1 isoparametric interpolation.

- class Tetra4

  Defines a three-dimensional 4-node tetrahedral finite element using P_1 interpolation.

- class Triang3

  Defines a 3-Node (P_1) triangle.

- class Triang6S

  Defines a 6-Node straight triangular finite element using P_2 interpolation.

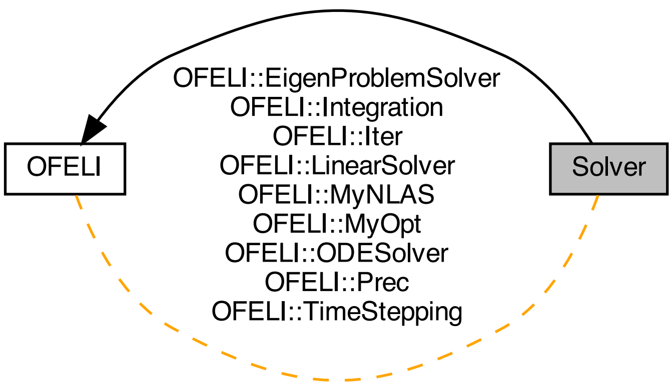
5.15.1 Detailed Description

Shape function classes.

5.16 Solver

Solver functions and classes.

Collaboration diagram for Solver:



Classes

- class Reconstruction

  To perform various reconstruction operations.
- class EigenProblemSolver

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

  Class for numerical integration methods.
- class Iter< T_ >

  Class to drive an iterative process.
- class LinearSolver< T_ >

  Class to solve systems of linear equations by iterative methods.
- class LPSolver

  To solve a linear programming problem.
- 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_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, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t &toler)

  Biconjugate gradient solver function.
- template<class T_ >
  int BiCG (const SpMatrix< T_ > &A, int prec, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler)

  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)

  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)

  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)

  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)

Conjugate gradient solver function.

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

  Conjugate Gradient Squared 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)

  Conjugate Gradient Squared solver function.

- ostream & operator<< (ostream &s, const EigenProblemSolver &es)

  Output eigenproblem information.

- 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)

  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)

  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)

  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)

  Jacobi solver function.

- ostream & operator<< (ostream &s, const LPSolver &os)

  Output solver information.

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

  SSOR solver function.

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

  Output differential system information.

5.16.1 Detailed Description

Solver functions and classes.

5.16.2 Macro Definition Documentation

#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:

```
OFELI::NbTimeSteps = int(OFELI::theFinalTime/
      OFELI::theTimeStep);    \
          for (OFELI::theTime=OFELI::theTimeStep,
      theStep=1;                   \
               theTime<OFELI::theFinalTime+0.001*
      OFELI::theTimeStep;            \
               OFELI::theTime+=OFELI::theTimeStep, ++
      OFELI::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*, const Prec< T_ > & *P*, const Vect< T_ > & *b*, Vect< T_ > & *x*, int *max_it*, real_t & *toler*)

Biconjugate gradient solver function.
This function uses the preconditioned Biconjugate Conjugate Gradient algorithm to solve a linear system with a sparse matrix.
The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function BiCG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual

- Verbosity >6 : Print final solution if convergence
- Verbosity >10 : Print obtained solution at each iteration

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*P*	Preconditioner (Instance of class Prec).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*max_it*	Maximum number of iterations.
	toler	[in] Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

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

Author

Rachid Touzani

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

Biconjugate gradient solver function.

This function uses the preconditioned Biconjugate Conjugate Gradient algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*prec*	Enum variable selecting a preconditioner, among the values `IDENT_PREC`, `DIAG_PREC`, `ILU_PREC` or `SSOR_PREC`

in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*max_it*	Maximum number of iterations.
	toler	[in] Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

<*T_*>	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*)

Biconjugate gradient stabilized solver function.

This function uses the preconditioned Conjugate Gradient Stabilized algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function BiCGStab
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*P*	Preconditioner (Instance of class Prec).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess on input and solution of the linear system on output (If iterations have succeeded).

in	*max_it*	Maximum number of iterations.
in	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

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

Author

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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*)

Biconjugate gradient stabilized solver function.

This function uses the preconditioned Conjugate Gradient Stabilized algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

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

Returns

Number of performed iterations,

Template Parameters

<T_>	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*)

Conjugate gradient solver function.

This function uses the preconditioned Conjugate Gradient algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

`in`	*A*	Problem matrix (Instance of class SpMatrix).
`in`	*P*	Preconditioner (Instance of class Prec).
`in`	*b*	Right-hand side vector (class Vect)
`in,out`	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
`in`	*max_it*	Maximum number of iterations.
`in`	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

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

Author

Rachid Touzani

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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*)

Conjugate gradient solver function.
This function uses the preconditioned Conjugate Gradient algorithm to solve a linear system with a sparse matrix.
The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

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

Returns

Number of performed iterations,

Template Parameters

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

Author

Rachid Touzani

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

Conjugate Gradient Squared solver function.
This function uses the preconditioned Conjugate Gradient Squared algorithm to solve a linear system with a sparse matrix.
The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message

- Verbosity > 1 : Notify executing the function CGS
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*P*	Preconditioner (Instance of class Prec).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*max_it*	Maximum number of iterations.
in	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations

Template Parameters

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

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*)

Conjugate Gradient Squared solver function.

This function uses the preconditioned Conjugate Gradient Squared algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

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

Returns

Number of performed iterations

Template Parameters

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

Author

Rachid Touzani

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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*)

GMRes solver function.

This function uses the preconditioned GMRES algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity <2 : No output message
- Verbosity >1 : Notify executing the function CMRes
- Verbosity >2 : Notify convergence with number of performed iterations or divergence
- Verbosity >3 : Output each iteration number and residual
- Verbosity >6 : Print final solution if convergence
- Verbosity >10 : Print obtained solution at each iteration

Parameters

`in`	*A*	Problem matrix (Instance of class SpMatrix).
`in`	*P*	Preconditioner (Instance of class Prec).

in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*m*	Number of subspaces to generate for iterations.
in	*max_it*	Maximum number of iterations.
in	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

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

Author

Rachid Touzani

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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*)

GMRes solver function.

This function uses the preconditioned GMRES algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function CG
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

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

Returns

Number of performed iterations,

Template Parameters

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

Author

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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*)

Gauss-Seidel solver function.

This function uses the relaxed Gauss-Seidel algorithm to solve a linear system with a sparse matrix.

The global variable Verbosity enables choosing output message level

- Verbosity < 2 : No output message
- Verbosity > 1 : Notify executing the function GS
- Verbosity > 2 : Notify convergence with number of performed iterations or divergence
- Verbosity > 3 : Output each iteration number and residual
- Verbosity > 6 : Print final solution if convergence
- Verbosity > 10 : Print obtained solution at each iteration

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*omega*	Relaxation parameter.
in	*max_it*	Maximum number of iterations.
in	*toler*	Tolerance for convergence (measured in relative weighted 2-↩ Norm).

Returns

Number of performed iterations

Template Parameters

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

Author

Rachid Touzani

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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*)

Jacobi solver function.

Parameters

in	*A*	Problem matrix (Instance of class SpMatrix).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*omega*	Relaxation parameter.
in	*max_it*	Maximum number of iterations.
in,out	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Parameters

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

Author

Rachid Touzani

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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	*A*	Problem matrix problem (Instance of abstract class **M_**).
in	*b*	Right-hand side vector (class Vect)
	x	Vect 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 (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

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

Author

Rachid Touzani

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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

```
| A  U |  |x|   |b|
|      |  | | = | |
| L  D |  |y|   |c|
```

Parameters

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

Template Argument:
Template Parameters

<T_>	data type (real_t, float, ...)

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

SSOR solver function.

Parameters

in	*A*	Problem matrix (Instance of abstract class **M_**).
in	*b*	Right-hand side vector (class Vect)
in,out	*x*	Vect instance containing initial solution guess in input and solution of the linear system in output (If iterations have succeeded).
in	*max_it*	Maximum number of iterations.
in	*toler*	Tolerance for convergence (measured in relative weighted 2-Norm).

Returns

Number of performed iterations,

Template Arguments:

- *T_* data type (double, float, ...)

- *M_* Matrix storage class

  Author

  Rachid Touzani

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ostream & operator<< **(ostream &** *s*, **TimeStepping &** *ts* **)**

Output differential system information.

Author

Rachid Touzani

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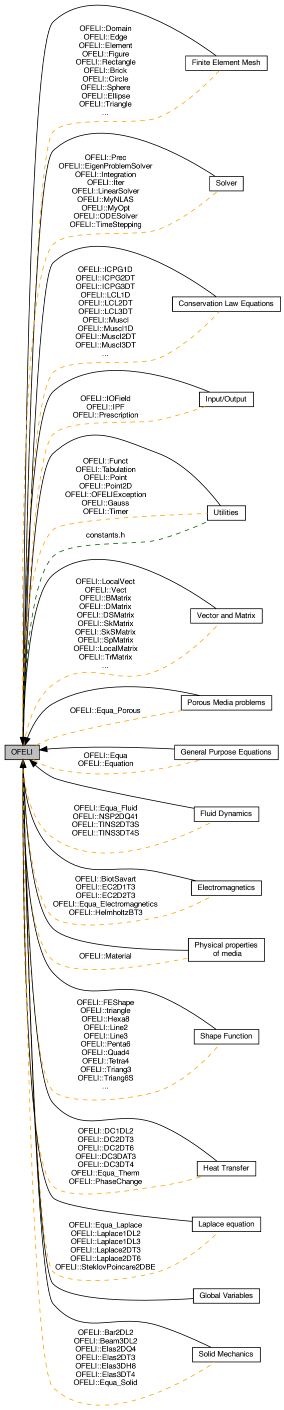
5.17 OFELI

Collaboration diagram for OFELI:



Modules

- Conservation Law Equations

  Conservation law equations.
- Electromagnetics

  Electromagnetic equations.
- General Purpose Equations

  Gathers equation related classes.
- Fluid Dynamics

  Fluid Dynamics equations.
- Laplace equation

  Laplace and Poisson equations.
- Porous Media problems

  Porous Media equation classes.
- Solid Mechanics

  Solid Mechanics finite element equations.
- Heat Transfer

  Heat Transfer equations.
- Input/Output

  Input/Output utility classes.
- Utilities

  Utility functions and classes.
- Physical properties of media

  Physical properties of materials and media.
- Global Variables

  All global variables in the library.
- Finite Element Mesh

  Mesh management classes
- Shape Function

  Shape function classes.
- Solver

  Solver functions and classes.
- Vector and Matrix

  Vector and matrix classes.

Files

- 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 Equa.h

  Definition file for abstract class Equa.
- 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 Laplace2DT3.h

  Definition file for class Laplace2DT3.
- file Laplace2DT6.h

  Definition file for class Laplace2DT6.
- 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 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 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 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 Integration.h

  Definition file for numerical integration class.
- 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 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< 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 Equa

  Mother abstract class to describe equation.
- class Equation< NEN_, NEE_, NSN_, NSE_ >

  Abstract class for all equation classes.
- class Equa_Fluid< 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 penaly 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 tatrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.
- class FastMarching

  class for the fast marching algorithm on uniform grids
- class FastMarching1DG

  class for the fast marching algorithm on 1-D uniform grids
- class FastMarching2DG

  class for the fast marching algorithm on 2-D uniform grids
- class FastMarching3DG

  class for the fast marching algorithm on 3-D uniform grids
- class Equa_Laplace< 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 Laplace2DT3

  To build element equation for the Laplace equation using the 2-D triangle element (P_1).
- class Laplace2DT6

  To build element equation for the Laplace equation using the 2-D triangle element (P_2).

- class SteklovPoincare2DBE
  Solver of the Steklov Poincare problem in 2-D geometries using piecewie constant boundary elemen.
- class Equa_Porous< 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< 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< 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 BMatrix< T_ >

  To handle band matrices.
- class DMatrix< T_ >

  To handle dense matrices.
- class DSMatrix< T_ >

  To handle symmetric dense matrices.
- 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 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 Point< T_ >

  Defines a point with arbitrary type coordinates.
- class Point2D< T_ >

  Defines a 2-D point with arbitrary type coordinates.
- 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 Q1-isoparametric interpolation.
- class Line2

    To describe a 2-Node 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 Integration

  Class for numerical integration methods.

- 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 ODESolver

  To solve a system of ordinary differential equations.

- class TimeStepping

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

- class Gauss

  Calculate data for Gauss integration.

- class Timer

  To handle elapsed time counting.

Enumerations

- enum PDE_Terms {
  CONSISTENT_MASS = 0x00001000,
  LUMPED_MASS = 0x00002000,
  MASS = 0x00002000,
  CAPACITY = 0x00004000,
  CONSISTENT_CAPACITY = 0x00004000,
  LUMPED_CAPACITY = 0x00008000,
  VISCOSITY = 0x00010000,
  STIFFNESS = 0x00020000,
  DIFFUSION = 0x00040000,
  MOBILITY = 0x00040000,
  CONVECTION = 0x00080000,
  DEVIATORIC = 0x00100000,
  DILATATION = 0x00200000,
  ELECTRIC = 0x00400000,
  MAGNETIC = 0x00800000,
  LOAD = 0x01000000,
  HEAT_SOURCE = 0x02000000,
  BOUNDARY_TRACTION = 0x04000000,
  HEAT_FLUX = 0x08000000,
  CONTACT = 0x10000000,
  BUOYANCY = 0x20000000,
  LORENTZ_FORCE = 0x40000000 }

- enum Analysis {
STATIONARY = 0,
STEADY_STATE = 0,
TRANSIENT = 1,
TRANSIENT_ONE_STEP = 2,
OPTIMIZATION = 3,
EIGEN = 4 }
- enum TimeScheme {
NONE = 0,
FORWARD_EULER = 1,
BACKWARD_EULER = 2,
CRANK_NICOLSON = 3,
HEUN = 4,
NEWMARK = 5,
LEAP_FROG = 6,
ADAMS_BASHFORTH = 7,
AB2 = 7,
RUNGE_KUTTA = 8,
RK4 = 8,
RK3_TVD = 9,
BDF2 = 10,
BUILTIN = 11 }
- enum FEType {
FE_2D_3N,
FE_2D_6N,
FE_2D_4N,
FE_3D_AXI_3N,
FE_3D_4N,
FE_3D_8N }
- enum AccessType

  Enumerated values for file access type.
- enum MatrixType {
DENSE = 1,
SKYLINE = 2,
SPARSE = 4,
DIAGONAL = 8,
TRIDIAGONAL = 16,
BAND = 32,
SYMMETRIC = 64,
UNSYMMETRIC = 128,
IDENTITY = 256 }
- enum Iteration {
DIRECT_SOLVER = 0,
CG_SOLVER = 1,
CGS_SOLVER = 2,
BICG_SOLVER = 3,
BICG_STAB_SOLVER = 4,
GMRES_SOLVER = 5 }

  Choose iterative solver for the linear system.
- enum Preconditioner {

IDENT_PREC = 0,
DIAG_PREC = 1,
DILU_PREC = 2,
ILU_PREC = 3,
SSOR_PREC = 4 }

Choose preconditioner for the linear system.

- enum BCType {
PERIODIC_A = 9999,
PERIODIC_B = -9999,
CONTACT_BC = 9998,
CONTACT_M = 9997,
CONTACT_S = -9997,
SLIP = 9996 }
- enum IntegrationScheme {
LEFT_RECTANGLE = 0,
RIGHT_RECTANGLE = 1,
MID_RECTANGLE = 2,
TRAPEZOIDAL = 3,
SIMPSON = 4,
GAUSS_LEGENDRE = 5 }

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.
- 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 x)

  Return the calculated value of the function.
- real_t getDerivative (string funct, real_t x)

  Return the derivative of the function at a given point.
- real_t getValue (string funct, real_t x, real_t y)

  Return the calculated value of the function.
- real_t getValue (string funct, real_t x, real_t y, real_t z)

  Return the calculated value of the function.
- real_t getValue (string funct, real_t x, real_t y, real_t z, real_t t)

  Return the calculated value of the function.
- size_t getNbFuncts () const

  Get the Number of read functions.
- size_t getNbVar (size_t n) const

  Get number of variables of a given function.
- string getFunctName (size_t n) const

  Get the name of a read function.
- size_t getSize (size_t n, size_t i) const

  Get number of points defining tabulation.
- real_t getMinVar (size_t n, size_t i) const

  Get minimal value of a variable.
- real_t getMaxVar (size_t n, size_t i) const

Get maximal value of a variable.

- Point< real_t > CrossProduct (const Point< real_t > &lp, const Point< real_t > &rp)

  Return Cross product of two vectors `lp` *and* `rp`
- 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 Vect< RC > &I, int opt=1)

  Constructor for a square matrix using non zero row and column indices.
- SpMatrix (const Vect< RC > &I, const Vect< T_ > &a, int opt=1)

  Constructor for a square matrix using non zero row and column indices.
- SpMatrix (size_t nr, size_t nc, const vector< size_t > &row_ptr, const vector< size_t > &col↩_ind)

  Constructor for a rectangle matrix.
- SpMatrix (size_t nr, size_t nc, const vector< size_t > &row_ptr, const vector< size_t > &col↩_ind, const vector< T_ > &a)

  Constructor for a rectangle matrix.
- SpMatrix (const vector< size_t > &row_ptr, const vector< size_t > &col_ind)

  Constructor for a rectangle matrix.
- SpMatrix (const vector< size_t > &row_ptr, const vector< size_t > &col_ind, const vector< T_ > &a)

  Constructor for a rectangle matrix.
- SpMatrix (const SpMatrix &m)

  Copy constructor.
- ~SpMatrix ()

  Destructor.
- void Identity ()

  Define matrix as identity.
- void Dense ()

  Define matrix as a dense one.
- 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)
- T_ operator() (size_t i) const

  Operator () with one argument (Constant version)
- 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 $a*x$ and add to y.
- void TMult (const Vect< T_ > &x, Vect< T_ > &y) const

  Multiply transpose of matrix by vector x and save in y.
- void Axpy (T_ a, const SpMatrix< 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 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, bool fact=false)

  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.
- 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 diagona one and assign value `a` to all diagonal entries.
- void Laplace1D (real_t h)

  Define matrix as the one of 3-point finite difference discretization of the second derivative.
- 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 Axpy (T_ a, const TrMatrix< 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 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, bool fact=true)

  Solve a linear system with current matrix (forward and back substitution).
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=false)

  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.*
- Grid ()

  Construct a default grid with 10 intervals in each direction.
- Grid (real_t xm, real_t xM, size_t npx)

  Construct a 1-D structured grid given its extremal coordinates and number of intervals.
- Grid (real_t xm, real_t xM, real_t ym, real_t yM, size_t npx, size_t npy)

  Construct a 2-D structured grid given its extremal coordinates and number of intervals.
- Grid (Point< real_t > m, Point< real_t > M, size_t npx, size_t npy)

  Construct a 2-D structured grid given its extremal coordinates and number of intervals.
- Grid (real_t xm, real_t xM, real_t ym, real_t yM, real_t zm, real_t zM, size_t npx, size_t npy, size_t npz)

  Construct a 3-D structured grid given its extremal coordinates and number of intervals.
- Grid (Point< real_t > m, Point< real_t > M, size_t npx, size_t npy, size_t npz)

  Construct a 3-D structured grid given its extremal coordinates and number of intervals.
- void setXMin (const Point< real_t > &x)

  Set min. coordinates of the domain.
- void setXMax (const Point< real_t > &x)
- void setDomain (real_t xmin, real_t xmax)

  Set Dimensions of the domain: 1-D case.
- void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax)

  Set Dimensions of the domain: 2-D case.
- void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax, real_t zmin, real_t zmax)

  Set Dimensions of the domain: 3-D case.
- void setDomain (Point< real_t > xmin, Point< real_t > xmax)

  Set Dimensions of the domain: 3-D case.

- const Point< real_t > & getXMin () const

  Return min. Coordinates of the domain.
- const Point< real_t > & getXMax () const

  Return max. Coordinates of the domain.
- void setN (size_t nx, size_t ny=0, size_t nz=0)

  Set number of grid intervals in the x, y and z-directions.
- void setNbDOF (size_t n)

  Set number of degrees of freedom for a node [Default: 1].
- 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.
- size_t getNbNodes () const

  Return total number of grid nodes.
- size_t getNbDOF () const

  Return total number of dof.
- 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.
- Iter ()

  Default Constructor.
- Iter (int max_it, real_t toler)

  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)

5.17.1 Detailed Description

5.17.2 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 Analysis

Selects Analysis type

Enumerator

STATIONARY Steady State analysis
STEADY_STATE Steady state analysis
TRANSIENT Transient problem
TRANSIENT_ONE_STEP Transient problem, perform only one time step
OPTIMIZATION Optimization problem
EIGEN Eigenvalue problem

enum TimeScheme

Selects Time integration scheme

Enumerator

NONE No time integration scheme
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)
BUILTIN Builtin scheme, implemented in equation class

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 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 Metod
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 condition (first side)

PERIODIC_B Periodic Boundary condition (second side)

CONTACT_BC Contact Boundary conditions

CONTACT_M Contact Boundary condition, set as master side

CONTACT_S Contact Boundary condition, set as slave side

SLIP Slip Boundary condition

enum IntegrationScheme

Choose numerical integration scheme

Enumerator

LEFT_RECTANGLE Left rectangle integration formula

RIGHT_RECTANGLE Right rectangle integration formula

MID_RECTANGLE Midpoint (central) rectangle formula

TRAPEZOIDAL Trapezoidal rule

SIMPSON Simpson formula

GAUSS_LEGENDRE Gauss-Legendre quadrature formulae

5.17.3 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	*file*	File name.
in	*access*	Access code. This number is to be chosen among two enumerated values: • `IOField::IN` to read the file • `IOField::OUT` to write on it
in	*compact*	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	*mesh_file*	File containing mesh
in	*file*	File that contains field stored or to store
in	*ms*	Mesh instance
in	*access*	Access code. This number is to be chosen among two enumerated values: • `IOField::IN` to read the file • `IOField::OUT` to write on it
in	*compact*	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	*file*	File that contains field stored or to store
in	*ms*	Mesh instance
in	*access*	Access code. This number is to be chosen among two enumerated values: • `IOField::IN` to read the file • `IOField::OUT` to write on it

in	*compact*	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	*file*	File that contains field stored or to store
in	*access*	Access code. This number is to be chosen among two enumerated values: • `IOField::IN` to read the file • `IOField::OUT` to write on it
in	*name*	Seek a specific field with given *name*

void setMeshFile (const string & *file*)

Set mesh file.

Parameters

in	*file*	Mesh file

void open ( )

Open file.

Case where file name has been previously given (in the constructor).

void open (const string & *file*, AccessType *access*)

Open file.

Parameters

in	*file*	File name.
in	*access*	Access code. This number is to be chosen among two enumerated values: • `IOField::IN` to read the file • `IOField::OUT` to write on it

void put (const Vect< real_t > & *v*)

Store Vect instance v in file.

Parameters

in	*v*	Vect 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`	*v*	Vect instance
`in`	*name*	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`	*A*	DMatrix instance
`in`	*name*	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`	*A*	DSMatrix instance
`in`	*name*	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`	*v*	Vector instance
`in`	*t*	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`	*output_file*	Output file name where to store using **GMSH** format

in	*mesh_file*	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 *x*)

Return the calculated value of the function.
Case of a function of one variable
Parameters

in	*funct*	Name of the function to be evaluated, as read from input file
in	*x*	Value of the variable

Returns

Computed value of the function

real_t getDerivative (string *funct*, real_t *x*)

Return the derivative of the function at a given point.
Case of a function of one variable
Parameters

in	*funct*	Name of the function to be evaluated, as read from input file
in	*x*	Value of the variable

Returns

Derivative value

real_t getValue (string *funct*, real_t *x*, real_t *y*)

Return the calculated value of the function.
Case of a function of two variables
Parameters

in	*funct*	Name of the function to be evaluated, as read from input file
in	*x*	Value of the first variable
in	*y*	Value of the second variable

Returns

Computed value of the function

real_t getValue (string *funct*, real_t *x*, real_t *y*, real_t *z*)

Return the calculated value of the function.
Case of a function of three variables

Parameters

in	*funct*	Name of the funct to be evaluated, as read from input file
in	*x*	Value of the first variable
in	*y*	Value of the second variable
in	*z*	Value of the third variable

Returns

Computed value of the function

real_t getValue (string *funct*, real_t *x*, real_t *y*, real_t *z*, real_t *t*)

Return the calculated value of the function.

Case of a function of three variables

Parameters

in	*funct*	Name of the funct to be evaluated, as read from input file
in	*x*	Value of the first variable
in	*y*	Value of the second variable
in	*z*	Value of the third variable
in	*t*	Value of the fourth variable

Returns

Computed value of the function

size_t getNbFuncts ( ) const

Get the Number of read functions.

Returns

size_t Number of functions

size_t getNbVar (size_t *n*) const

Get number of variables of a given function.

Parameters

in	*n*	index of function

Returns

Number of variables

string getFunctName (size_t *n*) const

Get the name of a read function.

Parameters

in	*n*	index of function

Returns

Name of function

size_t getSize (size_t *n*, size_t *i*) const

Get number of points defining tabulation.
Parameters

in	*n*	index of function (Starting from 1)
in	*i*	index of variable (Between 1 and 3)

Returns

Size

real_t getMinVar (size_t *n*, size_t *i*) const

Get minimal value of a variable.
Parameters

in	*n*	index of function
in	*i*	index of variable (Between 1 and 3)

Returns

Minimal value

real_t getMaxVar (size_t *n*, size_t *i*) const

Get maximal value of a variable.
Parameters

in	*n*	index of function
in	*i*	index of variable (between 1 and 3)

Returns

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	*nr*	Number of matrix rows.
in	*nc*	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	*size*	Number of matrix rows (and columns).
in	*is_diagonal*	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	*mesh*	Mesh instance from which matrix graph is extracted.
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.
in	*is_diagonal*	Boolean argument to say is the matrix is actually a diagonal matrix or not.

SpMatrix (const Vect< RC > & *I*, int *opt* = `1`)

Constructor for a square matrix using non zero row and column indices.

Parameters

in	*I*	Vector containing pairs of row and column indices
in	*opt*	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

SpMatrix (const Vect< RC > & *I*, const Vect< T_ > & *a*, int *opt* = `1`)

Constructor for a square matrix using non zero row and column indices.

Parameters

in	*I*	Vector containing pairs of row and column indices
in	*a*	Vector containing matrix entries in the same order than the one given by `I`
in	*opt*	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

SpMatrix (size_t ***nr,*** **size_t** ***nc,*** **const vector< size_t > &** ***row_ptr,*** **const vector< size_t > &** ***col_ind*** **)**

Constructor for a rectangle matrix.

Parameters

in	*nr*	Number of rows
in	*nc*	Number of columns
in	*row_ptr*	Vector of row pointers (See the above description of this class).
in	*col_ind*	Vector of column indices (See the above description of this class).

SpMatrix (size_t *nr*, size_t *nc*, const vector< size_t > & *row_ptr*, const vector< size_t > & *col_ind*, const vector< T_ > & *a*)

Constructor for a rectangle matrix.
Parameters

in	*nr*	Number of rows
in	*nc*	Number of columns
in	*row_ptr*	Vector of row pointers (See the above description of this class).
in	*col_ind*	Vector of column indices (See the above description of this class).
in	*a*	vector instance containing matrix entries stored columnwise

SpMatrix (const vector< size_t > & *row_ptr*, const vector< size_t > & *col_ind*)

Constructor for a rectangle matrix.
Parameters

in	*row_ptr*	Vector of row pointers (See the above description of this class).
in	*col_ind*	Vector of column indices (See the above description of this class).

SpMatrix (const vector< size_t > & *row_ptr*, const vector< size_t > & *col_ind*, const vector< T_ > & *a*)

Constructor for a rectangle matrix.
Parameters

in	*row_ptr*	Vector of row pointers (See the above description of this class).
in	*col_ind*	Vector of column indices (See the above description of this class).
in	*a*	vector instance that contain matrix entries stored row by row. Number of rows is extracted from vector `row_ptr`.

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*	Mesh 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 **set←Penal**(..).

Parameters

in	*mesh*	Mesh instance from which information is extracted.
in,out	*b*	Vect instance that contains right-hand side.
in	*u*	Vect 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 **set←Penal**(..).

Parameters

in,out	*b*	Vect instance that contains right-hand side.
in	*u*	Vect 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	*size*	Number of rows and columns.

void setSize (size_t *nr*, size_t *nc*)

Set size (number of rows) of matrix.

Parameters

in	*nr*	Number of rows
in	*nc*	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*	Vector containing pairs of row and column indices
in	*opt*	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*	Row index
in	*j*	Column index

Implements Matrix< T_ >.

T_ operator() (size_t *i*, size_t *j*) const `[virtual]`

Operator () (Constant version)

Parameters

in	i	Row index
in	j	Column index

Implements Matrix< 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.

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	x	Vect 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	x	Vector to multiply by matrix
out	y	Vector that contains on output the result.

Implements Matrix< T_ >.

void Axpy (T_ *a*, const SpMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.
Parameters

in	a	Scalar to premultiply
in	m	Matrix by which a is multiplied. The result is added to current instance

void Axpy (T_ *a*, const Matrix< T_ > * *m*) [virtual]

Add to matrix the product of a matrix by a scalar.
Parameters

in	a	Scalar to premultiply
in	m	Pointer to Matrix by which a is multiplied. The result is added to current instance

Implements Matrix< T_ >.

void set (size_t *i*, size_t *j*, const T_ & *val*) [virtual]

Assign a value to an entry of the matrix.
Parameters

in	i	Row index
in	j	Column index
in	val	Value to assign to a(i,j)

Implements Matrix< T_ >.

void add (size_t *i*, size_t *j*, const T_ & *val*) `[virtual]`

Add a value to an entry of the matrix.

Parameters

in	*i*	Row index
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*, bool *fact* = *false*) [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
in	*fact*	Unused argument

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	*solver*	Option to choose iterative solver in an enumerated variable • `CG_SOLVER`: Conjugate Gradient [default] • `CGS_SOLVER`: Squared conjugate gradient • `BICG_SOLVER`: Biconjugate gradient • `BICG_STAB_SOLVER`: Biconjugate gradient stabilized • `GMRES_SOLVER`: Generalized Minimal Residual Default value is `CG_SOLVER`
in	*prec*	Option to choose preconditioner in an enumerated variable • `IDENT_PREC`: Identity preconditioner (no preconditioning) • `DIAG_PREC`: Diagonal preconditioner [default] • `SSOR_PREC`: SSOR (Symmetric Successive Over Relaxation) preconditioner • `DILU_PREC`: ILU (Diagonal Incomplete factorization) preconditioner • `ILU_PREC`: ILU (Incomplete factorization) preconditioner Default value is `DIAG_PREC`
in	*max_it*	Maximum number of allowed iterations. Default value is `1000`.
in	*toler*	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*	Row index (Starting from 1)
in	*j*	Column index (Starting from 1)

Implements Matrix< T_ >.

TrMatrix ( )

Default constructor.
Initialize a zero dimension tridiagonal matrix

void Laplace1D (real_t *h*)

Define matrix as the one of 3-point finite difference discretization of the second derivative.

Parameters

in	*h*	mesh size

void setSize (size_t *size*)

Set size (number of rows) of matrix.
Parameters

in	*size*	Number of rows and columns.

void Axpy (T_ *a*, const TrMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.
Parameters

in	*a*	Scalar to premultiply
in	*m*	Matrix by which a is multiplied. The result is added to current instance

void Axpy (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*, bool *fact* = true) [virtual]

Solve a linear system with current matrix (forward and back substitution).
Parameters

in,out	*b*	Vect instance that contains right-hand side on input and solution on output.
in	*fact*	Unused argument

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*, bool *fact* = false) [virtual]

Solve a linear system with current matrix (forward and back substitution).
Parameters

in	*b*	Vect instance that contains right-hand side.
out	*x*	Vect instance that contains solution.
in	*fact*	Unused argument

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_ >.

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	*xm*	Minimal value for x
in	*xM*	Maximal value for x
in	*npx*	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	*xm*	Minimal value for x
in	*xM*	Maximal value for x
in	*ym*	Minimal value for y
in	*yM*	Maximal value for y
in	*npx*	Number of grid intervals in the x-direction
in	*npy*	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	*m*	Minimal coordinate value
in	*M*	Maximal coordinate value
in	*npx*	Number of grid intervals in the x-direction
in	*npy*	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	*xm*	Minimal value for x
in	*xM*	Maximal value for x
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	*npy*	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 *npy*, 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	*npy*	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	*xmin*	Minimal value of x-coordinate
in	*xmax*	Maximal value of x-coordinate
in	*ymin*	Minimal value of y-coordinate
in	*ymax*	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	*xmin*	Minimal value of x-coordinate
in	*xmax*	Maximal value of x-coordinate
in	*ymin*	Minimal value of y-coordinate
in	*ymax*	Maximal value of y-coordinate
in	*zmin*	Minimal value of z-coordinate
in	*zmax*	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	*xmin*	Minimal coordinate value
in	*xmax*	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	*nx*	Number of grid intervals in the x-direction
in	*ny*	Number of grid intervals in the y-direction (Default=0: 1-D grid)
in	*nz*	Number of grid intervals in the z-direction (Default=0: 1-D or 2-D grid)

Remarks

: The size of the grid (`xmin` and `xmax`) must have been defined before.

size_t getNy ( ) const

Return number of grid intervals in the y-direction.
`ny=0` for 1-D domains (segments)

size_t getNz ( ) const

Return number of grid intervals in the z-direction.
`nz=0` for 1-D (segments) and 2-D domains (rectangles)

void setCode (string *exp*, int *code*)

Set a code for some grid points.
Parameters

in	*exp*	Regular expression that determines the set of grid points on which the code is applied.
in	*code*	Code to assign.

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

Set a code for grid points on sides.
Parameters

in	*side*	Side for which code is assigned. Possible values are: `MIN_X`, `MAX_X`, `MIN_Y`, `MAX_Y`, `MIN_Z`, `MAX_Z`
in	*code*	Code to assign.

int getCode (int *side*) const

Return code for a side number.
Parameters

in	*side*	Side for which code is returned. Possible values are: `MIN_X`, `MAX_X`, `MIN_Y`, `MAX_Y`, `MIN_Z`, `MAX_Z`

int getCode (size_t *i*, size_t *j*) const

Return code for a grid point.

Parameters

in	*i*	i-th index for node for which code is to be returned.
in	*j*	j-th index for node for which code is to be returned.

int getCode (size_t *i*, size_t *j*, size_t *k*) const

Return code for a grid point.
Parameters

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

void Deactivate (size_t *i*)

Change state of a cell from active to inactive (1-D grid)
Parameters

in	*i*	grid cell to remove

void Deactivate (size_t *i*, size_t *j*)

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

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

Returns

1 if cell is active, 0 if not

int isActive (size_t *i*, size_t *j*) const

Say if cell is active or not (2-D grid)
Parameters

in	*i*	i-th index of cell
in	*j*	j-th index of cell

Returns

1 if cell is active, 0 if not

int isActive (size_t *i*, size_t *j*, size_t *k*) const

Say if cell is active or not (3-D grid)
Parameters

in	*i*	i-th index of cell
in	*j*	j-th index of cell
in	*k*	k-th index of cell

Returns

1 if cell is active, 0 if not

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*)

Constructor with iteration parameters.
Parameters

in	*max_it*	Maximum number of iterations
in	*toler*	Tolerance value for convergence

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

Check convergence.

Parameters

`in,out`	*u*	Solution vector at previous iteration
`in`	*v*	Solution vector at current iteration
`in`	*opt*	Vector norm for convergence checking 1: 1-norm, 2: 2-norm, 0: Max. norm [Default: 2]

Returns

true if convergence criterion is satisfied, false if not

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

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`.

Chapter 6

Namespace Documentation

6.1 OFELI Namespace Reference

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

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 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 Discontinous 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 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 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

  Mother abstract class to describe equation.
- 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 FastMarching

  class for the fast marching algorithm on uniform grids
- class FastMarching1DG

  class for the fast marching algorithm on 1-D uniform grids
- class FastMarching2DG

  class for the fast marching algorithm on 2-D uniform grids
- class FastMarching3DG

  class for the fast marching algorithm on 3-D 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 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 Integration

  Class for numerical integration methods.
- 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 Laplace2DT3

  To build element equation for the Laplace equation using the 2-D triangle element (P_1).
- class Laplace2DT6

  To build element equation for the Laplace equation using the 2-D triangle element (P_2).
- 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 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 LPSolver

  To solve a linear programming problem.
- 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 penaly 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 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 piecewie 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 tatrahedral 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

  To store and treat a triangle.

- class triangle

  Defines a triangle. The reference element is the rectangle triangle with two unit edges.

- class TrMatrix

  To handle tridiagonal matrices.

- class Vect

  To handle general purpose vectors.

- class WaterPorous2D

  To solve water flow equations in porous media (1-D)

Enumerations

- enum PDE_Terms {
  CONSISTENT_MASS = 0x00001000,
  LUMPED_MASS = 0x00002000,
  MASS = 0x00002000,
  CAPACITY = 0x00004000,
  CONSISTENT_CAPACITY = 0x00004000,
  LUMPED_CAPACITY = 0x00008000,
  VISCOSITY = 0x00010000,
  STIFFNESS = 0x00020000,
  DIFFUSION = 0x00040000,
  MOBILITY = 0x00040000,
  CONVECTION = 0x00080000,
  DEVIATORIC = 0x00100000,
  DILATATION = 0x00200000,
  ELECTRIC = 0x00400000,
  MAGNETIC = 0x00800000,
  LOAD = 0x01000000,
  HEAT_SOURCE = 0x02000000,
  BOUNDARY_TRACTION = 0x04000000,
  HEAT_FLUX = 0x08000000,
  CONTACT = 0x10000000,
  BUOYANCY = 0x20000000,
  LORENTZ_FORCE = 0x40000000 }
- enum Analysis {
  STATIONARY = 0,
  STEADY_STATE = 0,
  TRANSIENT = 1,
  TRANSIENT_ONE_STEP = 2,
  OPTIMIZATION = 3,
  EIGEN = 4 }
- enum TimeScheme {
  NONE = 0,
  FORWARD_EULER = 1,
  BACKWARD_EULER = 2,
  CRANK_NICOLSON = 3,
  HEUN = 4,
  NEWMARK = 5,
  LEAP_FROG = 6,
  ADAMS_BASHFORTH = 7,
  AB2 = 7,
  RUNGE_KUTTA = 8,
  RK4 = 8,
  RK3_TVD = 9,
  BDF2 = 10,
  BUILTIN = 11 }
- enum FEType {
  FE_2D_3N,
  FE_2D_6N,
  FE_2D_4N,
  FE_3D_AXI_3N,
  FE_3D_4N,
  FE_3D_8N }

- enum MatrixType {
  DENSE = 1,
  SKYLINE = 2,
  SPARSE = 4,
  DIAGONAL = 8,
  TRIDIAGONAL = 16,
  BAND = 32,
  SYMMETRIC = 64,
  UNSYMMETRIC = 128,
  IDENTITY = 256 }
- enum Iteration {
  DIRECT_SOLVER = 0,
  CG_SOLVER = 1,
  CGS_SOLVER = 2,
  BICG_SOLVER = 3,
  BICG_STAB_SOLVER = 4,
  GMRES_SOLVER = 5 }

  Choose iterative solver for the linear system.
- enum Preconditioner {
  IDENT_PREC = 0,
  DIAG_PREC = 1,
  DILU_PREC = 2,
  ILU_PREC = 3,
  SSOR_PREC = 4 }

  Choose preconditioner for the linear system.
- enum NormType {
  NORM1,
  WNORM1,
  NORM2,
  WNORM2,
  NORM_MAX }
- enum BCType {
  PERIODIC_A = 9999,
  PERIODIC_B = -9999,
  CONTACT_BC = 9998,
  CONTACT_M = 9997,
  CONTACT_S = -9997,
  SLIP = 9996 }
- enum IntegrationScheme {
  LEFT_RECTANGLE = 0,
  RIGHT_RECTANGLE = 1,
  MID_RECTANGLE = 2,
  TRAPEZOIDAL = 3,
  SIMPSON = 4,
  GAUSS_LEGENDRE = 5 }

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::list< T_ > &l)
  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 (const Vect< real_t > &v, const Mesh &mesh, string output_file, int opt)
  Save a 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, int f=1)
  Save a vector to an input `Gnuplot` *file.*
- void saveGnuplot (Mesh &mesh, string input_file, string output_file, int f=1)
  Save a vector to an input `Gnuplot` *file.*
- void saveTecplot (string input_file, string output_file, string mesh_file, int f=1)
  Save a vector to an output file to an input `Tecplot` *file.*
- void saveTecplot (Mesh &mesh, string input_file, string output_file, int f=1)
  Save a vector to an output file to an input `Tecplot` *file.*
- void saveVTK (string input_file, string output_file, string mesh_file, int f=1)
  Save a vector to an output `VTK` *file.*
- void saveVTK (Mesh &mesh, string input_file, string output_file, int f=1)
  Save a vector to an output `VTK` *file.*
- void saveGmsh (string input_file, string output_file, string mesh_file, int f=1)
  Save a vector to an output `Gmsh` *file.*
- void saveGmsh (Mesh &mesh, string input_file, string output_file, int f=1)
  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_>
  LocalVect< T_, NR_ > operator* (const LocalMatrix< T_, NR_, NC_ > &A, const LocalVect< T_, NC_ > &x)

  *Operator * (Multiply matrix A by vector x)*
- 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 Axpy (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_ >
  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< real_t > CrossProduct (const Point< real_t > &lp, const Point< real_t > &rp)

  Return Cross product of two vectors `lp` *and* `rp`
- bool areClose (const Point< real_t > &a, const Point< real_t > &b, real_t toler=OFELI_TOLERANCE)

  Return `true` *if both instances of class Point<double> are distant with less then* `toler`
- real_t SqrDistance (const Point< real_t > &a, const Point< real_t > &b)

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

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

  Return euclidean distance between points `a` *and* `b`
- bool operator< (const Point< size_t > &a, const Point< size_t > &b)

  Comparison operator. Returns true if all components of first vector are lower than those of second one.
- 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.
- template<class T_ >
  Vect< T_ > operator+ (const Vect< T_ > &x, const Vect< T_ > &y)

  Operator + (Addition of two instances of class Vect)
- template<class T_ >
  Vect< T_ > operator- (const Vect< T_ > &x, const Vect< T_ > &y)

  Operator - (Difference between two vectors of class Vect)
- template<class T_ >
  Vect< T_ > operator∗ (const T_ &a, const Vect< T_ > &x)

  Operator ∗ (Premultiplication of vector by constant)
- template<class T_ >
  Vect< T_ > operator∗ (const Vect< T_ > &x, const T_ &a)

  Operator ∗ (Postmultiplication of vector by constant)
- template<class T_ >
  Vect< T_ > operator/ (const Vect< T_ > &x, const T_ &a)

  Operator / (Divide vector entries by constant)
- template<class T_ >
  T_ Dot (const Vect< T_ > &x, const Vect< T_ > &y)

Calculate dot product of two vectors.
- real_t Discrepancy (Vect< real_t > &x, const Vect< real_t > &y, int n, int type=1)

  Return discrepancy between 2 vectors x and y
- real_t Discrepancy (Vect< complex_t > &x, const Vect< complex_t > &y, int n, int type=1)

  Return discrepancy between 2 vectors x and y
- void Modulus (const Vect< complex_t > &x, Vect< real_t > &y)

  Calculate modulus of complex vector.
- void Real (const Vect< complex_t > &x, Vect< real_t > &y)

  Calculate real part of complex vector.
- void Imag (const Vect< complex_t > &x, Vect< real_t > &y)

  Calculate imaginary part of complex vector.
- template<class T_ >
  istream & operator>> (istream &s, Vect< T_ > &v)
- template<class T_ >
  ostream & operator<< (ostream &s, const Vect< T_ > &v)

  Output vector 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 rate=0.2)

  Calculate deformed mesh using a displacement field.

- 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 (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 getMaxElementMeasure (const Mesh &m)

  Return maximal 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.
- 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, const Prec< T_ > &P, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t &toler)

  Biconjugate gradient solver function.

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

  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)

  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)

  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)

  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)

  Conjugate gradient solver function.

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

  Conjugate Gradient Squared 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)

  Conjugate Gradient Squared solver function.

- ostream & operator<< (ostream &s, const EigenProblemSolver &es)

  Output eigenproblem information.

- 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)

  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)

  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)

  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)

  Jacobi solver function.
- ostream & operator<< (ostream &s, const LPSolver &os)

  Output solver information.
- 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_ , class M_ >
  int SSOR (const M_ &A, const Vect< T_ > &b, Vect< T_ > &x, int max_it, real_t toler)

  SSOR solver function.
- ostream & operator<< (ostream &s, 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 Kronecker (int i, int j)

  Return Kronecker delta of `i` *and* `j`.
- 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)

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

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

  Mutiply 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 Axpy (size_t n, T_ a, T_ *x, T_ *y)

  Multiply array x by a and add result to y
- template<class T_ >
  void Axpy (T_ a, const vector< T_ > &x, vector< T_ > &y)

  Multiply vector x by a and add result to y
- template<class T_ >
  void Axpy (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)*
- 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.
- 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 Verbosity

  Verbosity parameter.
- int theStep

  Time step counter.
- int theIteration

  Iteration counter.
- int NbTimeSteps

  Number of time steps.
- int MaxNbIterations

  Maximal number of iterations.
- real_t theTimeStep

  Time step label.
- real_t theTime

  Time value.
- real_t theFinalTime

  Final time value.
- real_t theTolerance

  Tolerance value for convergence.
- real_t theDiscrepancy

  Value of discrepancy for an iterative procedure Its default value is `1.0`.
- bool Converged

  Boolean variable to say if an iterative procedure has converged.
- bool InitPetsc

6.1.1 Detailed Description

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

Namespace OFELI groups all OFELI library classes, functions and global variables.

6.1.2 Enumeration Type Documentation

enum NormType

Choose type of vector norm to compute

Enumerator

NORM1 1-norm

WNORM1 Weighted 1-norm (Discrete L1-Norm)

NORM2 2-norm

WNORM2 Weighted 2-norm (Discrete L2-Norm)

NORM_MAX Max-norm (Infinity norm)

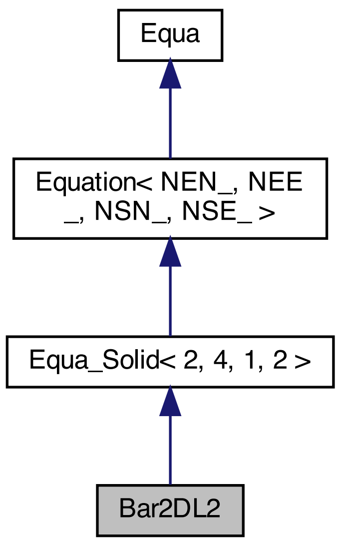
Chapter 7

Class Documentation

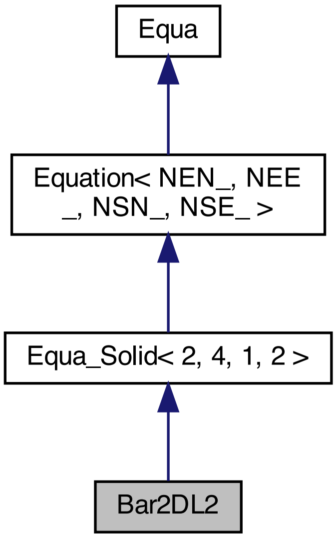
7.1 Bar2DL2 Class Reference

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

Inheritance diagram for Bar2DL2:



Collaboration diagram for Bar2DL2:



Public Member Functions

- Bar2DL2 ()

  Default Constructor.
- Bar2DL2 (Mesh &ms)

  Constructor using a Mesh instance.
- Bar2DL2 (Mesh &ms, Vect< real_t > &u)

  Constructor using a Mesh instance and a solution vector instance.
- ∼Bar2DL2 ()

  Destructor.
- void setSection (real_t A)

  Define bar section.
- void LMass (real_t coef=1)

  Add lumped mass matrix to element matrix after multiplying it by coefficient `coef`
- void Mass (real_t coef=1)

  Add consistent mass matrix to element matrix after multiplying it by coefficient `coef`
- void Stiffness (real_t coef=1.)

  Add element stiffness to left hand side.
- real_t Stress () const

  Return stresses in bar.
- void getStresses (Vect< real_t > &s)

  Return stresses in the truss structure (elementwise)
- void build ()

  Build the linear system of equations.

Additional Inherited Members

7.1.1 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.

7.1.2 Constructor & Destructor Documentation

Bar2DL2 ( )

Default Constructor.

Constructs an empty equation.

Bar2DL2 (Mesh & *ms*)

Constructor using a Mesh instance.

Parameters

`in`	*ms*	Reference Mesh instance

Bar2DL2 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using a Mesh instance and a solution vector instance.

Parameters

`in`	*ms*	Reference Mesh instance
`in,out`	*u*	Reference to solution vector

7.1.3 Member Function Documentation

void LMass (real_t *coef* = *1*) `[virtual]`

Add lumped mass matrix to element matrix after multiplying it by coefficient `coef`

Parameters

`in`	*coef*	Coefficient to multiply by added term [Default: `1`].

Reimplemented from Equa_Solid< 2, 4, 1, 2 >.

void Mass (real_t *coef* = *1*) `[virtual]`

Add consistent mass matrix to element matrix after multiplying it by coefficient `coef`

Parameters

`in`	*coef*	Coefficient to multiply by added term [Default: `1`].

Reimplemented from Equa_Solid< 2, 4, 1, 2 >.

void Stiffness (real_t *coef* = *1.*) `[virtual]`

Add element stiffness to left hand side.

Parameters

in	*coef*	Coefficient to multuply by added term [Default: 1].

Reimplemented from Equa_Solid< 2, 4, 1, 2 >.

void getStresses (Vect< real_t > & *s*)

Return stresses in the truss structure (elementwise)
Parameters

in	*s*	Vect instance containing axial stresses in elements

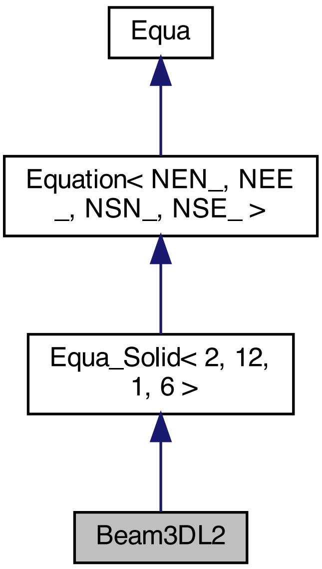
void build ( )

Build the linear system of equations.
Before using this function, one must have properly selected appropriate options for:

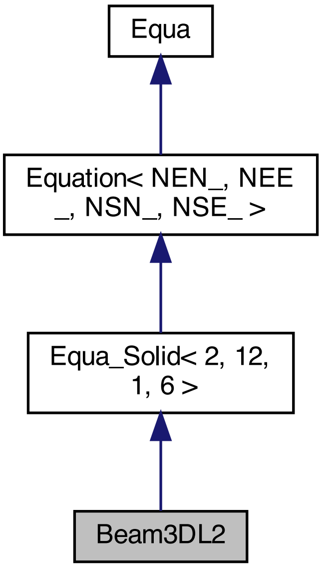
- The choice of a steady state or transient analysis
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent mass matrix
- The choice of desired linear system solver

7.2 Beam3DL2 Class Reference

To build element equations for 3-D beam equations using 2-node lines.
Inheritance diagram for Beam3DL2:



Collaboration diagram for Beam3DL2:



Public Member Functions

- Beam3DL2 ()

  Default Constructor.
- Beam3DL2 (Mesh &ms, real_t A, real_t I1, real_t I2)

  Constructor using mesh and constant beam properties.
- Beam3DL2 (Mesh &ms)

  Constructor using a Mesh instance.
- Beam3DL2 (Mesh &ms, Vect< real_t > &u)

  Constructor using a Mesh instance and solution vector.
- ∼Beam3DL2 ()

  Destructor.
- void set (real_t A, real_t I1, real_t I2)

  Set constant beam properties.
- void set (const Vect< real_t > &A, const Vect< real_t > &I1, const Vect< real_t > &I2)

  Set nonconstant beam properties.
- void getDisp (Vect< real_t > &d)

  Get vector of displacements at nodes.
- void LMass (real_t coef=1.)

  Add element lumped Mass contribution to element matrix after multiplication by `coef`
- void Mass (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 element matrix.
- 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.
- void AxialForce (Vect< real_t > &f)

    Return axial force in element.
- void ShearForce (Vect< real_t > &sh)

    Return shear force in element.
- void BendingMoment (Vect< real_t > &m)

    Return bending moment in element.
- void TwistingMoment (Vect< real_t > &m)

    Return twisting moments.
- void build ()

    Build the linear system of equations.
- void buildEigen (SkSMatrix< real_t > &K, Vect< real_t > &M)

    Build global stiffness and mass matrices for the eigen system.

Additional Inherited Members

7.2.1 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.

7.2.2 Constructor & Destructor Documentation

Beam3DL2 (Mesh & *ms*, real_t *A*, real_t *I1*, real_t *I2*)

Constructor using mesh and constant beam properties.

Parameters

in	*ms*	Mesh instance
in	*A*	Section area of the beam
in	*I1*	first (x) momentum of inertia
in	*I2*	second (y) momentum of inertia

Beam3DL2 (Mesh & *ms*)

Constructor using a Mesh instance.

Parameters

in	*ms*	Reference to Mesh instance

Beam3DL2 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using a Mesh instance and solution vector.

Parameters

in	*ms*	Reference to Mesh instance
in,out	*u*	Solution vector

7.2.3 Member Function Documentation

void set (real_t *A*, real_t *I1*, real_t *I2*)

Set constant beam properties.

Parameters

in	*A*	Section area of the beam
in	*I1*	first (x) momentum of inertia
in	*I2*	second (y) momentum of inertia

void set (const Vect< real_t > & *A*, const Vect< real_t > & *I1*, const Vect< real_t > & *I2*)

Set nonconstant beam properties.

Parameters

in	*A*	Vector containing section areas of the beam (for each element)
in	*I1*	Vector containing first (x) momentum of inertia (for each element)
in	*I2*	Vector containing second (y) momentum of inertia (for each element)

void getDisp (Vect< real_t > & *d*)

Get vector of displacements at nodes.

Parameters

out	*d*	Vector containing three components for each node that are `x`, `y` and `z` displacements.

void AxialForce (Vect< real_t > & f)

Return axial force in element.

Parameters

out	*f*	Vector containing axial force in each element. This vector is resized in the function

void ShearForce (Vect< real_t > & *sh*)

Return shear force in element.
Parameters

out	*sh*	Vector containing shear forces (2 components) in each element. This vector is resized in the function

void BendingMoment (Vect< real_t > & *m*)

Return bending moment in element.
Parameters

out	*m*	Vector containing bending moments (2 components) in each element. This vector is resized in the function

void TwistingMoment (Vect< real_t > & *m*)

Return twisting moments.
Parameters

out	*m*	Vector containing twisting moment in each element. This vector is resized in the function

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

7.3 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.

7.3.1 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.

Author

Rachid Touzani

Copyright

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7.3.2 Constructor & Destructor Documentation

BiotSavart (Mesh & ***ms*** **)**

Constructor using mesh data.

Parameters

in	*ms*	Mesh 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*	Mesh instance
in	*J*	Sidewise vector of current density (`J` is a real 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`]

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*	Mesh 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`]

7.3.3 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 (Vect 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 (Vect instance) of complex entries

void setMagneticInduction (Vect< real_t > & *B*)

Transmit (real) magnetic induction vector given at nodes.

Parameters

out	*B*	Magnetic induction vector (Vect instance) and real entries

void setMagneticInduction (Vect< complex_t > & *B*)

Transmit (complex) magnetic induction vector given at nodes.
Parameters

out	*B*	Magnetic induction vector (Vect 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 ( )

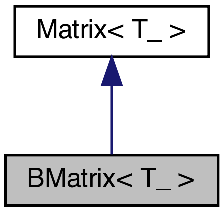
Run the calculation by the Biot-Savart formula.

This function computes the magnetic induction, which is stored in the vector `B` given in the constructor

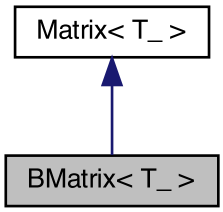
7.4 BMatrix< T_ > Class Template Reference

To handle band matrices.

Inheritance diagram for BMatrix< T_ >:



Collaboration 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, bool fact=false)
  Solve linear system.
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=false)
  Solve linear system.
- T_ * get () const
  Return C-Array.
- T_ get (size_t i, size_t j) const
  Return entry `(i,j)` *of matrix.*

7.4.1 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

Copyright

GNU Lesser Public License

7.4.2 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`	*size*	Number of rows and columns
`in`	*ld*	Number of lower co-diagonals (must be > 0)
`in`	*ud*	Number of upper co-diagonals (must be > 0)

7.4.3 Member Function Documentation

void setSize (size_t *size*, int *ld*, int *ud*)

Set size (number of rows) and storage of matrix.

Parameters

`in`	*size*	Number of rows and columns
`in`	*ld*	Number of lower co-diagonals (must be > 0)
`in`	*ud*	Number of upper co-diagonals (must be > 0)

void Axpy (T_ *a*, const BMatrix< T_ > & *x*)

Add to matrix the product of a matrix by a scalar.

Parameters

`in`	*a*	Scalar to premultiply
`in`	*x*	Matrix by which `a` is multiplied. The result is added to current instance

void Axpy (T_ *a*, const Matrix< T_ > ∗ *x*) `[virtual]`

Add to matrix the product of a matrix by a scalar.

Parameters

in	*a*	Scalar to premultiply
in	*x*	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_ >.

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*, bool *fact* = `false`) `[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`	*b*	Vect instance that contains right-hand side on input and solution on output.
`in`	*fact*	Unused argument

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*, bool *fact* = `false`) `[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`	*b*	Vect instance that contains right-hand side.
`out`	*x*	Vect instance that contains solution
`in`	*fact*	Unused argument

Returns

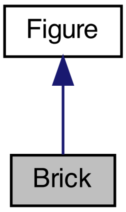
- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

Implements Matrix< T_ >.

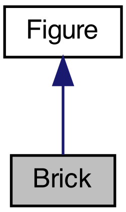
7.5 Brick Class Reference

To store and treat a brick (parallelepiped) figure.

Inheritance diagram for Brick:



Collaboration 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 ∗=.

7.5.1 Detailed Description

To store and treat a brick (parallelepiped) figure.

7.5.2 Constructor & Destructor Documentation

Brick (const Point< real_t > & *bbm*, const Point< real_t > & *bbM*, int *code* = *1*)

Constructor.
Parameters

in	*bbm*	first point (xmin,ymin,zmin)
in	*bbM*	second point (xmax,ymax,zmax)
in	*code*	Code to assign to rectangle

7.5.3 Member Function Documentation

void setBoundingBox (const Point< real_t > & *bbm*, const Point< real_t > & *bbM*)

Assign bounding box of the brick.
Parameters

in	*bbm*	first point (xmin,ymin,zmin)
in	*bbM*	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	*p*	Point<double> instance

Reimplemented from Figure.

Brick& operator+= (Point< real_t > *a*)

Operator +=.

Translate brick by a vector `a`

Brick& operator+= (real_t *a*)

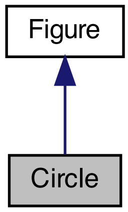
Operator ∗=.

Scale brick by a factor `a`

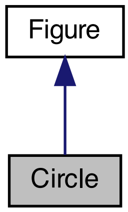
7.6 Circle Class Reference

To store and treat a circular figure.

Inheritance diagram for Circle:



Collaboration diagram for Circle:



Public Member Functions

- Circle ()

  Default construcor.
- 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 ∗=.

7.6.1 Detailed Description

To store and treat a circular figure.

7.6.2 Constructor & Destructor Documentation

Circle (const Point< real_t > & *c*, real_t *r*, int *code* = *1*)

Constructor.
Parameters

in	*c*	Coordinates of center of circle
in	*r*	Radius
in	*code*	Code to assign to the generated domain [Default: 1]

7.6.3 Member Function Documentation

real_t getSignedDistance (const Point< real_t > & *p*) const `[virtual]`

Return signed distance of a given point from the current circle.
The computed distance is negative if `p` lies in the disk, positive if it is outside, and 0 on the circle
Parameters

in	*p*	Point<double> instance

Reimplemented from Figure.

Circle& operator+= (Point< real_t > *a*)

Operator +=.
Translate circle by a vector `a`

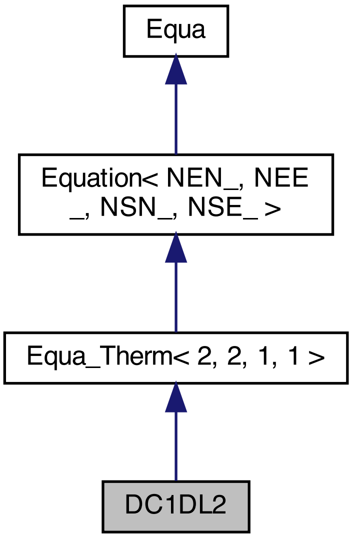
Circle& operator+= (real_t *a*)

Operator ∗=.
Scale circle by a factor `a`

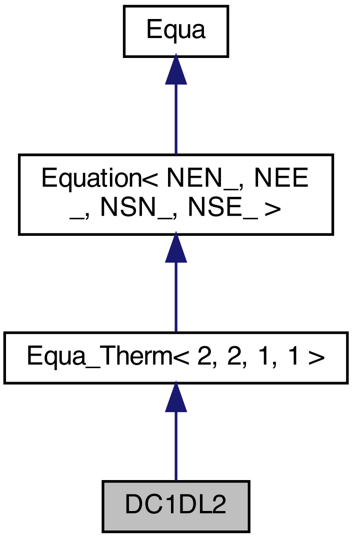
7.7 DC1DL2 Class Reference

Builds finite element arrays for thermal diffusion and convection in 1-D using 2-Node elements.

Inheritance diagram for DC1DL2:



Collaboration diagram for DC1DL2:



Public Member Functions

- DC1DL2 ()

  Default Constructor.
- DC1DL2 (Mesh &ms)
- DC1DL2 (Mesh &ms, Vect< real_t > &u)
- ~DC1DL2 ()

  Destructor.
- void LCapacity (real_t coef=1)

  Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`
- void Capacity (real_t coef=1)

  Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`*.*
- void Diffusion (real_t coef=1)

  Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const real_t &v, real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const Vect< real_t > &v, real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void BodyRHS (const Vect< real_t > &f)

  Add body right-hand side term to right hand side.
- real_t Flux () const

  Return (constant) heat flux in element.
- void setInput (EqDataType opt, Vect< real_t > &u)

  Set equation input data.

Additional Inherited Members

7.7.1 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.

7.7.2 Constructor & Destructor Documentation

DC1DL2 ( )

Default Constructor.

Constructs an empty equation.

DC1DL2 (Mesh & *ms*)

Constructor using mesh instance

Parameters

in	*ms*	Mesh instance

DC1DL2 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh instance and solution vector

Parameters

in	*ms*	Mesh instance
in,out	*u*	Vect instance containing solution vector

7.7.3 Member Function Documentation

void LCapacity (real_t *coef* = *1*) `[virtual]`

Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`

Parameters

in	*coef*	Coefficient to multiply by added term [default: 1]

Reimplemented from Equa_Therm< 2, 2, 1, 1 >.

void Capacity (real_t *coef* = *1*) `[virtual]`

Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`.

Parameters

in	*coef*	Coefficient to multiply by added term [default: 1]

Reimplemented from Equa_Therm< 2, 2, 1, 1 >.

void Diffusion (real_t *coef* = *1*) `[virtual]`

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`

Parameters

in	*coef*	Coefficient to multiply by added term [default: 1]

Reimplemented from Equa_Therm< 2, 2, 1, 1 >.

void Convection (const real_t & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`

Parameters

in	*v*	Constant velocity vector
in	*coef*	Coefficient to multiply by added term [default: 1]

void Convection (const Vect< real_t > & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`

Case where velocity field is given by a vector `v`

Parameters

in	*v*	Velocity vector
in	*coef*	Coefficient to multiply by added term [default: 1]

void Convection (real_t *coef* **=** *1* **)** [virtual]

Add convection matrix to element matrix after multiplying it by coefficient coef

Case where velocity field has been previouly defined

Parameters

in	*coef*	Coefficient to multiply by added term [default: 1]

Reimplemented from Equa_Therm< 2, 2, 1, 1 >.

void BodyRHS (const Vect< real_t > & *f* **)** [virtual]

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

Parameters

in	*f*	Vector containing source at nodes.

Reimplemented from Equa_Therm< 2, 2, 1, 1 >.

void setInput (EqDataType *opt*, **Vect< real_t > &** *u* **)**

Set equation input data.

Parameters

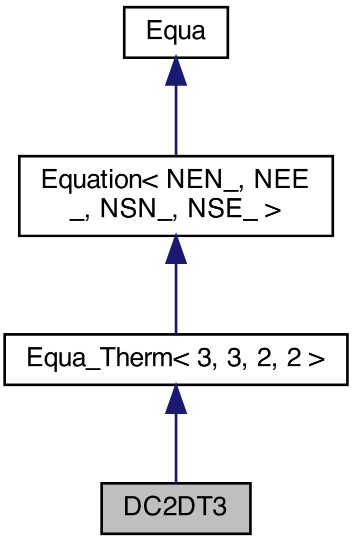
in	*opt*	Parameter that selects data type for input. This parameter is to be chosen in the enumerated variable EqDataType • INITIAL_FIELD: Initial temperature • BOUNDARY_CONDITION_DATA: Boundary condition (Dirichlet) • SOURCE_DATA: Heat source • FLUX_DATA: Heat flux (Neumann boundary condition) • VELOCITY: Velocity vector (for the convection term)

in	u	Vector containing input data

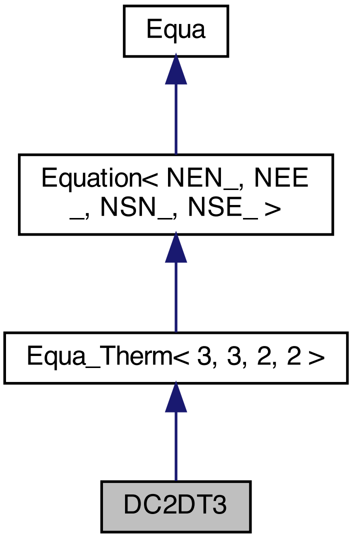
7.8 DC2DT3 Class Reference

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 3-Node triangles.

Inheritance diagram for DC2DT3:



Collaboration 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 ()

  Destructor.
- void LCapacity (real_t coef=1)

  Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`
- void Capacity (real_t coef=1)

  Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`
- void Diffusion (real_t coef=1)

  Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
- void Diffusion (const LocalMatrix< real_t, 2, 2 > &diff, real_t coef=1)

  Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const Point< real_t > &v, real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const Vect< real_t > &v, real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (real_t coef=1)

Add convection matrix to element matrix 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 (const Vect< real_t > &f)

  Add body right-hand side term to right hand side.
- void BodyRHS (real_t f)

  Add body right-hand side term to right hand side.
- void BoundaryRHS (real_t flux)

  Add boundary right-hand side flux to right hand side.
- void BoundaryRHS (const Vect< real_t > &f)

  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.
- void Grad (Vect< Point< real_t > > &g)

  Compute gradient of solution.
- 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.

Additional Inherited Members

7.8.1 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.

7.8.2 Constructor & Destructor Documentation

DC2DT3 (Mesh & *ms*)

Constructor using Mesh data.

Parameters

in	*ms*	Mesh instance

DC2DT3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh and initial condition.

Parameters

in	*ms*	Mesh instance
in	*u*	Vect instance containing initial solution

7.8.3 Member Function Documentation

void LCapacity (real_t *coef* = *1*) [virtual]

Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void Capacity (real_t *coef* = *1*) [virtual]

Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1]

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void Diffusion (real_t *coef* = *1*) [virtual]

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1]

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void Diffusion (const LocalMatrix< real_t, 2, 2 > & *diff*, real_t *coef* = *1*)

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
Case where the diffusivity matrix is given as an argument.
Parameters

in	*diff*	Diffusion matrix (class LocalMatrix).
in	*coef*	Coefficient to multiply by added term [Default: 1]

void Convection (const Point< real_t > & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*v*	Constant velocity vector
in	*coef*	Coefficient to multiply by added term [Default: 1]

void Convection (const Vect< real_t > & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`
Case where velocity field is given by a vector `v`

Parameters

in	*v*	Velocity vector
in	*coef*	Coefficient to multiply by added term (Default: 1]

void Convection (real_t *coef* = *1*) [virtual]

Add convection matrix to element matrix after multiplying it by coefficient `coef`

Case where velocity field has been previouly defined

Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1]

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void LinearExchange (real_t *coef*, real_t *T*)

Add an edge linear exchange term to left and right-hand sides.

Parameters

in	*coef*	Coefficient of exchange
in	*T*	External value for exchange

Remarks

This assumes a constant value of `T`

void BodyRHS (const Vect< real_t > & *f*) [virtual]

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

Parameters

in	*f*	Vector containing source at nodes.

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void BodyRHS (real_t *f*)

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

Case where the body right-hand side is piecewise constant.

Parameters

in	*f*	Value of thermal source (Constant in element).

void BoundaryRHS (real_t *flux*)

Add boundary right-hand side flux to right hand side.

Parameters

in	*flux*	Vector containing source at side nodes.

void BoundaryRHS (const Vect< real_t > & *f*) [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient `coef`

Parameters

in	*f*	Vector containing source at nodes

Reimplemented from Equa_Therm< 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`]

void Grad (Vect< Point< real_t > > & *g*)

Compute gradient of solution.

Parameters

in	*g*	Elementwise vector containing gradient of solution.

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) • `INITIAL_FIELD`: Initial temperature • `BOUNDARY_CONDITION_DATA`: Boundary condition (Dirichlet) • `SOURCE_DATA`: Heat source • `FLUX_DATA`: Heat flux (Neumann boundary condition) • `VELOCITY_FIELD`: Velocity vector (for the convection term)

in	*u*	Vector containing input data

void JouleHeating (const Vect< real_t > & *sigma*, const Vect< real_t > & *psi*)

Set Joule heating term as source.

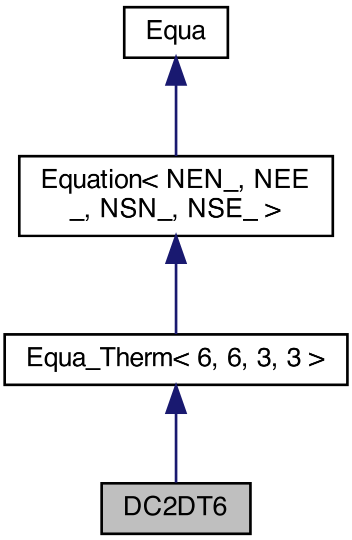
Parameters

in	*sigma*	Vect instance containing electric conductivity (elementwise)
in	*psi*	Vect instance containing electric potential (elementwise)

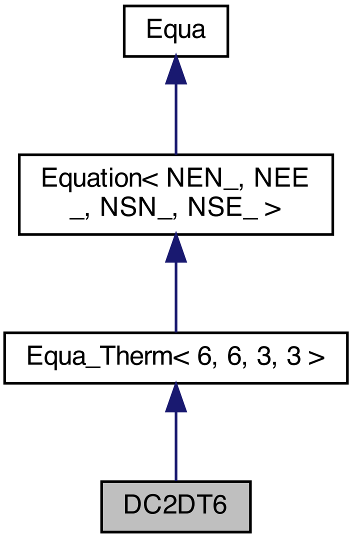
7.9 DC2DT6 Class Reference

Builds finite element arrays for thermal diffusion and convection in 2-D domains using 6-Node triangles.

Inheritance diagram for DC2DT6:



Collaboration diagram for DC2DT6:



Public Member Functions

- DC2DT6 ()

  Default Constructor.
- DC2DT6 (Mesh &ms)

  Constructor using Mesh data.
- DC2DT6 (Mesh &ms, Vect< real_t > &u)

  Constructor using Mesh data and solution vector.
- ∼DC2DT6 ()

  Destructor.
- void LCapacity (real_t coef=1)

  Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`.
- void Capacity (real_t coef=1)

  Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`.
- void Diffusion (real_t coef=1)

  Add diffusion matrix to element matrix 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 > &f)

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 after multiplying it by coefficient `coef`

Additional Inherited Members

7.9.1 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.

7.9.2 Constructor & Destructor Documentation

DC2DT6 ( )

Default Constructor.

Constructs an empty equation.

DC2DT6 (Mesh & *ms*)

Constructor using Mesh data.

Parameters

in	*ms*	Mesh instance

DC2DT6 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh data and solution vector.

Parameters

in	*ms*	Mesh instance
in,out	*u*	Vect instance containing solution vector

7.9.3 Member Function Documentation

void LCapacity (real_t *coef* = *1*) `[virtual]`

Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`.

Parameters

in	*coef*	Coefficient to multiply by added term (default value = 1).

Reimplemented from Equa_Therm< 6, 6, 3, 3 >.

void Capacity (real_t *coef* = *1*) `[virtual]`

Add Consistent capacity matrix to element matrix after multiplying it by coefficient `coef`.

Parameters

in	*coef*	Coefficient to multiply by added term (default value = 1).

Reimplemented from Equa_Therm< 6, 6, 3, 3 >.

void Diffusion (real_t *coef* = *1*) [virtual]

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 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 previouly defined
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 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	*v*	Constant velocity vector.
in	*coef*	Coefficient to multiply by added term [Default: 1].

void Convection (const Vect< real_t > & *v*, real_t *coef* = *1*)

Add convection matrix to left-hand side after multiplying it by coefficient `coef`
Case where velocity field is given by a vector `v`
Parameters

in	*v*	Velocity vector.
in	*coef*	Coefficient to multiply by added term [Default: 1].

void BodyRHS (const Vect< real_t > & *f*) [virtual]

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

in	*f*	Local vector (of size 6) containing source at nodes

Reimplemented from Equa_Therm< 6, 6, 3, 3 >.

void BoundaryRHS (const Vect< real_t > & *f*) [virtual]

Add boundary right-hand side term to right hand side after multiplying it by coefficient `coef`

Parameters

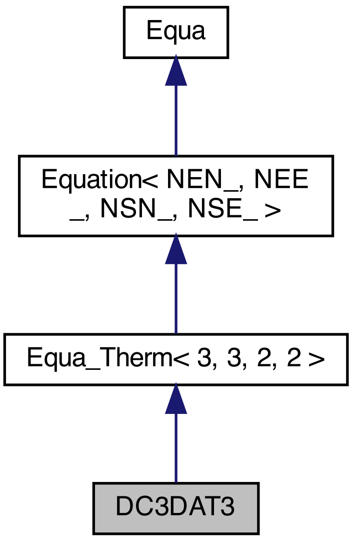
in	*f*	Vector containing source at nodes

Reimplemented from Equa_Therm< 6, 6, 3, 3 >.

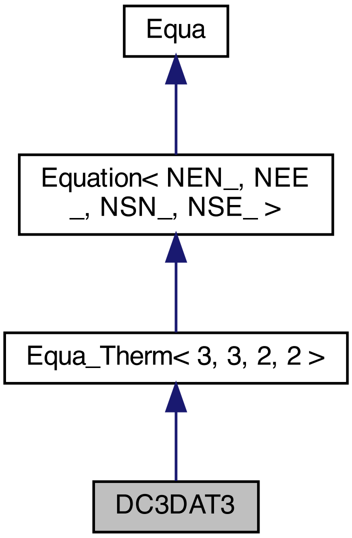
7.10 DC3DAT3 Class Reference

Builds finite element arrays for thermal diffusion and convection in 3-D domains with axisymmetry using 3-Node triangles.

Inheritance diagram for DC3DAT3:



Collaboration diagram for DC3DAT3:



Public Member Functions

- DC3DAT3 ()

  Default Constructor.
- DC3DAT3 (Mesh &ms)

  Constructor using Mesh data.
- DC3DAT3 (Mesh &ms, Vect< real_t > &u)

  Constructor using Mesh data and solution vector.
- ~DC3DAT3 ()

  Destructor.
- void LCapacity (real_t coef=1)

  Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`.
- void Capacity (real_t coef=1)

  Add Consistent capacity matrix to element matrix 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 BodyRHS (const Vect< real_t > &f)

  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 > &f)

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.

Additional Inherited Members

7.10.1 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.

7.10.2 Constructor & Destructor Documentation

DC3DAT3 ( )

Default Constructor.

Constructs an empty equation.

DC3DAT3 (Mesh & *ms*)

Constructor using Mesh data.

Parameters

`in`	*ms*	Mesh instance

DC3DAT3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh data and solution vector.

Parameters

`in`	*ms*	Mesh instance
`in,out`	*u*	Vect instance containing solution vector

7.10.3 Member Function Documentation

void LCapacity (real_t *coef* = *1*) `[virtual]`

Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`.

Parameters

`in`	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void Capacity (real_t *coef* = *1*) `[virtual]`

Add Consistent capacity matrix to element matrix after multiplying it by coefficient`coef`

Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void Diffusion (real_t *coef* = *1*) `[virtual]`

Add diffusion matrix to left-hand side after multiplying it by coefficient `coef`

Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 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	*diff*	Instance of class DMatrix containing diffusivity matrix
in	*coef*	Coefficient to multiply by added term [Default: 1]

void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

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

Parameters

in	*f*	Local vector (of size 3) containing source at odes.

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

void BoundaryRHS (real_t *flux*)

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

Parameters

in	*flux*	Value of flux to impose on the side

void BoundaryRHS (const Vect< real_t > & *f*) `[virtual]`

Add boundary right-hand side term to right hand side after multiplying it by coefficient `coef`

Parameters

in	*f*	Vector containing source at nodes

Reimplemented from Equa_Therm< 3, 3, 2, 2 >.

Point<real_t>& Grad (const Vect< real_t > & *u*)

Return gradient of a vector in element.

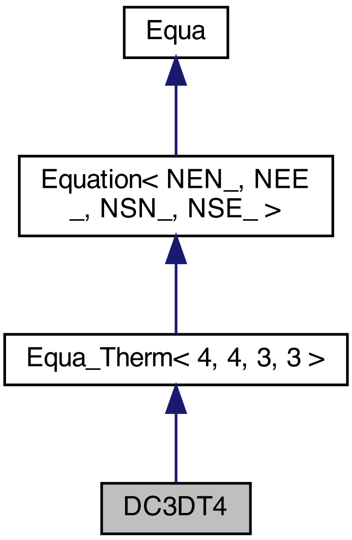
Parameters

in	*u*	Vector for which gradient is computed.

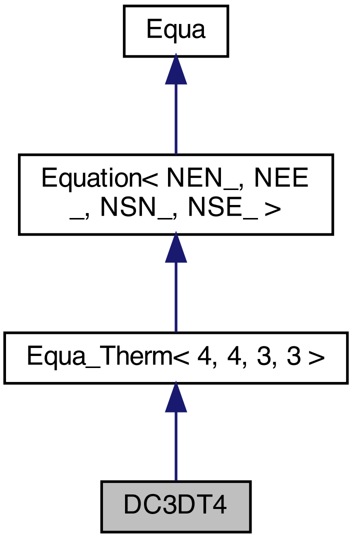
7.11 DC3DT4 Class Reference

Builds finite element arrays for thermal diffusion and convection in 3-D domains using 4-Node tetrahedra.

Inheritance diagram for DC3DT4:



Collaboration diagram for DC3DT4:



Public Member Functions

- DC3DT4 ()

  Default Constructor.
- DC3DT4 (Mesh &ms)

  Constructor using Mesh data.
- DC3DT4 (Mesh &ms, Vect< real_t > &u)

  Constructor using Mesh and initial condition.
- ~DC3DT4 ()

  Destructor.
- void LCapacity (real_t coef=1)

  Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`
- void Capacity (real_t coef=1)

  Add consistent capacity matrix to element matrix after multiplying it by coefficient `coef`
- void Diffusion (real_t coef=1)

  Add diffusion matrix to element matrix after multiplying it by coefficient `coef`.
- void Diffusion (const DMatrix< real_t > &diff, real_t coef=1)

  Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const Point< real_t > &v, real_t coef=1)

  Add convection matrix to element matrix after multiplying it by coefficient `coef`
- void Convection (const Vect< Point< real_t > > &v, real_t coef=1)

Add convection matrix to element matrix after multiplying it by coefficient `coef`

- void BodyRHS (const Vect< real_t > &f)

  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 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.
- void Grad (Vect< Point< real_t > > &g)

  Compute gradient of solution.
- void Periodic (real_t coef=1.e20)

  Add contribution of periodic boundary condition (by a penalty technique).

Additional Inherited Members

7.11.1 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.

7.11.2 Constructor & Destructor Documentation

DC3DT4 ( )

Default Constructor.

Constructs an empty equation.

DC3DT4 (Mesh & *ms*)

Constructor using Mesh data.

Parameters

`in`	*ms*	Mesh instance

DC3DT4 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh and initial condition.

Parameters

`in`	*ms*	Mesh instance
`in`	*u*	Vect instance containing initial solution

7.11.3 Member Function Documentation

void LCapacity (real_t *coef* = *1*) `[virtual]`

Add lumped capacity matrix to element matrix after multiplying it by coefficient `coef`

Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void Capacity (real_t *coef* = *1*) `[virtual]`

Add consistent capacity matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void Diffusion (real_t *coef* = *1*) `[virtual]`

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`.
Parameters

in	*coef*	Coefficient to multiply by added term (default value = 1).

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void Diffusion (const DMatrix< real_t > & *diff*, real_t *coef* = *1*)

Add diffusion matrix to element matrix after multiplying it by coefficient `coef`
Case where the diffusivity matrix is given as an argument.
Parameters

in	*diff*	Diffusion matrix (class DMatrix).
in	*coef*	Coefficient to multiply by added term [Default: 1].

void Convection (real_t *coef* = *1*) `[virtual]`

Add convection matrix to element matrix after multiplying it by coefficient `coef`
Case where velocity field has been previouly defined
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void Convection (const Point< real_t > & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`
Parameters

in	*v*	Constant velocity vector
in	*coef*	Coefficient to multiply by added term [Default: 1].

void Convection (const Vect< Point< real_t > > & *v*, real_t *coef* = *1*)

Add convection matrix to element matrix after multiplying it by coefficient `coef`
Case where velocity field is given by a vector `v`.

Parameters

`in`	*v*	Velocity vector.
`in`	*coef*	Coefficient to multiply by added term [Default: `1`].

void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

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

`in`	*f*	Vector containing source at nodes.

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void BoundaryRHS (const Vect< real_t > & *f*) `[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`	*f*	Vector containing source at nodes.

Reimplemented from Equa_Therm< 4, 4, 3, 3 >.

void BoundaryRHS (real_t *flux*)

Add boundary right-hand side flux to right hand side.
Parameters

`in`	*flux*	Vector containing source at side nodes.

void Grad (Vect< Point< real_t > > & *g*)

Compute gradient of solution.
Parameters

`in`	*g*	Elementwise vector containing gradient of solution.

void Periodic (real_t *coef* = *1.e20*)

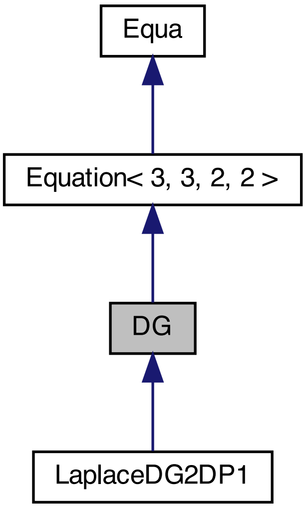
Add contribution of periodic boundary condition (by a penalty technique).
Boundary nodes where periodic boundary conditions are to be imposed must have codes equal to `PERIODIC_A` on one side and `PERIODIC_B` on the opposite side.
Parameters

`in`	*coef*	Value of penalty parameter [Default: `1.e20`].

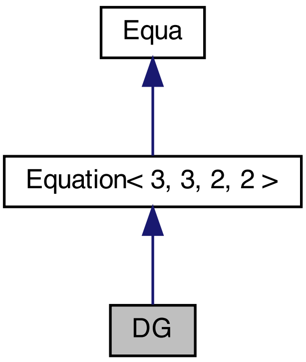
7.12 DG Class Reference

Enables preliminary operations and utilities for the Discontinous Galerkin method.

Inheritance diagram for DG:



Collaboration 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.

7.12.1 Detailed Description

Enables preliminary operations and utilities for the Discontinous Galerkin method.

Author

Rachid Touzani

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7.12.2 Constructor & Destructor Documentation

DG (Mesh & *ms*, size_t *degree* = 1)

Constructor with mesh and degree of the method.

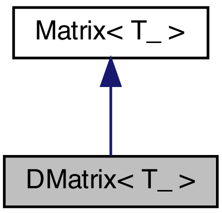
Parameters

in	*ms*	Mesh instance
in	*degree*	Polynomial degree of the DG method [Default: 1]

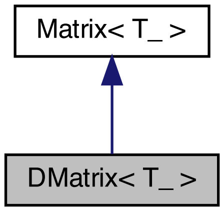
7.13 DMatrix< T_ > Class Template Reference

To handle dense matrices.

Inheritance diagram for DMatrix< T_ >:



Collaboration 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*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, bool fact=true)

  Solve linear system.
- int solveTrans (Vect< T_ > &b, bool fact=true)

  Solve the transpose linear system.
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)

  Solve linear system.

- int solveTrans (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)

  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.

7.13.1 Detailed Description

template<class T_>class OFELI::DMatrix< T_ >

To handle dense matrices.

This class enables storing and manipulating general dense matrices. Matrices can be square or rectangle ones.

Template Parameters

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

Author

Rachid Touzani

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7.13.2 Constructor & Destructor Documentation

DMatrix ( )

Default constructor.

Initializes a zero-dimension matrix.

DMatrix (size_t *nr*)

Constructor for a matrix with `nr` rows and `nr` columns.

Matrix entries are set to `0`.

DMatrix (size_t *nr*, size_t *nc*)

Constructor for a matrix with `nr` rows and `nc` columns.
Matrix entries are set to 0.

DMatrix (Vect< T_ > & *v*)

Constructor that uses a Vect instance. The class uses the memory space occupied by this vector.
Parameters

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	*mesh*	Mesh 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.
in	*is_diagonal*	Boolean argument to say is the matrix is actually a diagonal matrix or not.

7.13.3 Member Function Documentation

void setDiag (const T_ & *a*)

Set matrix as diagonal and assign its diagonal entries as a constant.
Parameters

in	*a*	Value to assign to all diagonal entries

void setDiag (const vector< T_ > & *d*)

Set matrix as diagonal and assign its diagonal entries.
Parameters

in	*d*	Vector entries to assign to matrix diagonal entries

void setSize (size_t *size*)

Set size (number of rows) of matrix.

Parameters

in	*size*	Number of rows and columns.

void setSize (size_t *nr*, size_t *nc*)

Set size (number of rows and columns) of matrix.
Parameters

in	*nr*	Number of rows.
in	*nc*	Number of columns.

void getColumn (size_t *j*, Vect< T_ > & *v*) const

Get `j`-th column vector.
Parameters

in	*j*	Index of column to extract
out	*v*	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	*j*	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*	Index of row to extract
out	*v*	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*	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*	row index of matrix
in	*j*	column index of matrix
in	*val*	Value to assign to `a(i,j)`.

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*	row index to be assigned
in	*v*	Vect 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	*j*	column index to be assigned
in	*v*	Vect 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	*a*	constant to multiply by
in	*x*	Vector to multiply by a
in,out	*y*	on input, vector to add to. On output, result.

Implements Matrix< T_ >.

void MultAdd (const Vect< T_ > & *x*, Vect< T_ > & *y*) const [virtual]

Multiply matrix by vector x and add result to y.
Parameters

in	*x*	Vector to add to y
in,out	*y*	on input, vector to add to. On output, result.

Implements Matrix< T_ >.

void Mult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const [virtual]

Multiply matrix by vector x and save result in y.
Parameters

in	*x*	Vector to add to y
out	*y*	Result.

Implements Matrix< T_ >.

void TMult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const [virtual]

Multiply transpose of matrix by vector x and add result in y.
Parameters

in	*x*	Vector to add to y
in,out	*y*	on input, vector to add to. On output, result.

Implements Matrix< T_ >.

void add (size_t *i*, size_t *j*, const T_ & *val*) [virtual]

Add constant `val` to entry `(i,j)` of the matrix.
Parameters

in	*i*	row index
in	*j*	column index
in	*val*	Constant to add

Implements Matrix< T_ >.

void Axpy (T_ *a*, const DMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.
Parameters

in	*a*	Scalar to premultiply

in	m	Matrix by which `a` is multiplied. The result is added to current instance

void Axpy (T_ *a*, const Matrix< T_ > * *m*) `[virtual]`

Add to matrix the product of a matrix by a scalar.
Parameters

in	a	Scalar to premultiply
in	m	Matrix by which `a` is multiplied. The result is added to current instance

Implements Matrix< T_ >.

int setQR ( )

Construct a QR factorization of the matrix.

This function constructs the QR decomposition using the Householder method. The upper triangular matrix R is returned in the upper triangle of the current matrix, except for the diagonal elements of R which are stored in an internal vector. The orthogonal matrix Q is represented as a product of n-1 Householder matrices Q1 . . . Qn-1, where Qj = 1 - uj.uj /cj . The i-th component of uj is zero for i = 1, ..., j-1 while the nonzero components are returned in a[i][j] for i = j, ..., 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 Q1 . . . Qn-1, where Qj = 1 - uj.uj /cj . The i-th component of uj is zero for i = 1, ..., j-1 while the nonzero components are returned in a[i][j] for i = j, ..., n.

Returns

`0` if the decomposition was successful, `k` is the `k-th` row is singular

Remarks

The matrix can be square or rectangle

int solveQR (const Vect< T_ > & *b*, Vect< T_ > & *x*)

Solve a linear system by QR decomposition.

This function constructs the QR decomposition, if this was not already done by using the member function QR and solves the linear system

Parameters

in	b	Right-hand side vector
out	x	Solution vector. Must have been sized before using this function.

Returns

The same value as returned by the function QR

int solveTransQR (const Vect< T_ > & *b*, Vect< T_ > & *x*)

Solve a transpose linear system by QR decomposition.

This function constructs the QR decomposition, if this was not already done by using the member function QR and solves the linear system

Parameters

in	b	Right-hand side vector
out	x	Solution vector. Must have been sized before using this function.

Returns

The same value as returned by the function QR

T_ operator() (size_t *i*, size_t *j*) const `[virtual]`

Operator () (Constant version). Return `a(i,j)`

Parameters

in	i	row index
in	j	column index

Implements Matrix< T_ >.

T_& operator() (size_t *i*, size_t *j*) `[virtual]`

Operator () (Non constant version). Return `a(i,j)`

Parameters

in	i	row index
in	j	column index

Implements Matrix< T_ >.

int setLU ( )

Factorize the matrix (LU factorization)

LU factorization of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- `0` if factorization was normally performed,
- `n` if the `n`-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

int setTransLU ( )

Factorize the transpose of the matrix (LU factorization)

LU factorization of the transpose of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- `0` if factorization was normally performed,
- `n` if the `n`-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

int solve (Vect< T_ > & *b*, bool *fact* = `true`) `[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`	*b*	Vect instance that contains right-hand side on input and solution on output.
`in`	*fact*	Set true if matrix is to be factorized (Default value), false if not

Returns

- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

Implements Matrix< T_ >.

int solveTrans (Vect< T_ > & *b*, bool *fact* = `true`)

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	*b*	Vect instance that contains right-hand side on input and solution on output.
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

Returns

- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

int solve (const Vect< T_ > & *b*, Vect< T_ > & *x*, bool *fact* = `true`) `[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	*b*	Vect instance that contains right-hand side.
out	*x*	Vect instance that contains solution
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

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*, bool *fact* = `true`)

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	*b*	Vect instance that contains right-hand side.
out	*x*	Vect instance that contains solution
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

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.

7.14 Domain Class Reference

To store and treat finite element geometric information.

Public Member Functions

- Domain ()

  Constructor of a null domain.
- Domain (const string &file)

  Constructor with an input file.
- ~Domain ()

  Destructor.
- void setFile (string file)

Set file containing Domain data.

- void setDim (size_t d)

  Set space dimension.
- size_t getDim () const

  Return space dimension.
- void setNbDOF (size_t n)

  Set number of degrees of freedom.
- size_t getNbDOF () const

  Return number of degrees of freedom.
- size_t getNbVertices () const

  Return number of vertices.
- size_t getNbLines () const

  Return number of lines.
- size_t getNbContours () const

  Return number of contours.
- size_t getNbHoles () const

  Return number of holes.
- size_t getNbSubDomains () const

  Return number of sub-domains.
- int get ()

  Read domain data interactively.
- void get (const string &file)

  Read domain data from a data file.
- Mesh & getMesh () const

  Return reference to generated Mesh instance.
- void genGeo (string file)

  Generate geometry file.
- void genMesh ()

  Generate 2-D mesh.
- void genMesh (const string &file)

  Generate 2-D mesh and save in file (OFELI format)
- void genMesh (string geo_file, string bamg_file, string mesh_file)

  Generate 2-D mesh and save geo, bamg and mesh file (OFELI format)
- void generateMesh ()

  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 circluar arc.

- void insertCircle (size_t n1, size_t n2, size_t n3, int dc, int nc)

  Insert a circluar 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.

7.14.1 Detailed Description

To store and treat finite element geometric information.

This class is essentially useful to construct data for mesh generators.

Author

Rachid Touzani

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7.14.2 Constructor & Destructor Documentation

Domain ( )

Constructor of a null domain.

This constructor assigns maximal values of parameters.

Domain (const string & *file*)

Constructor with an input file.

Parameters

in	*file*	Input file in the XML format defining the domain

7.14.3 Member Function Documentation

void get (const string & *file*)

Read domain data from a data file.
Parameters

in	*file*	Input file in Domain 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	*geo_file*	Geo file
in	*bamg_file*	Bamg file
in	*mesh_file*	File where the generated mesh is saved

Domain& operator*= (real_t *a*)

Operator *=
Rescale domain coordinates by myltiplying by a factor
Parameters

in	*a*	Value to multiply by

void insertVertex (real_t *x*, real_t *y*, real_t *h*, int *code*)

Insert a vertex.
Parameters

in	*x*	x-coordinate of vertex
in	*y*	y-coordinate of vertex
in	*h*	mesh size around vertex
in	*code*	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	*x*	x-coordinate of vertex
in	*y*	y-coordinate of vertex
in	*z*	z-coordinate of vertex
in	*h*	mesh size around vertex
in	*code*	code of coordinate

void insertLine (size_t *n1*, size_t *n2*, int *c*)

Insert a straight line.
Parameters

in	*n1*	Label of the first vertex of line
in	*n2*	Label of the second vertex of line
in	*c*	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	*n1*	Label of the first vertex of line
in	*n2*	Label of the second vertex of line
in	*dc*	Code to associate to created nodes (Dirichlet)
in	*nc*	Code to associate to created sides (Neumann)

void insertCircle (size_t *n1*, size_t *n2*, size_t *n3*, int *c*)

Insert a circluar arc.
Parameters

in	*n1*	Label of vertex defining the first end of the arc
in	*n2*	Label of vertex defining the second end of the arc
in	*n3*	Label of vertex defining the center of the arc
in	*c*	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 circluar arc.
Parameters

in	*n1*	Label of vertex defining the first end of the arc
in	*n2*	Label of vertex defining the second end of the arc
in	*n3*	Label of vertex defining the center of the arc
in	*dc*	Code to associate to created nodes (Dirichlet)

in	*nc*	Code to associate to created sides (Neumann)

void insertRequiredVertex (size_t *v*)

Insert a required (imposed) vertex.
Parameters

in	*v*	Label of vertex

void insertRequiredEdge (size_t *e*)

Insert a required (imposed) edge (or line)
Parameters

in	*e*	Label of line

void insertSubDomain (size_t *n*, int *code*)

Insert subdomain.
Parameters

in	*n*	
in	*code*	

void insertSubDomain (size_t *ln*, int *orient*, int *code*)

Insert subdomain.
Parameters

in	*ln*	Line label
in	*orient*	Orientation (1 or -1)
in	*code*	Subdomain code or reference

void setOutputFile (string *file*)

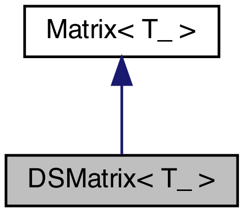
Define output mesh file.
Parameters

in	*file*	String defining output mesh file

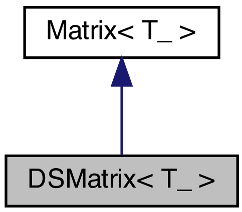
7.15 DSMatrix< T_ > Class Template Reference

To handle symmetric dense matrices.

Inheritance diagram for DSMatrix< T_ >:



Collaboration diagram for DSMatrix< T_ >:



Public Member Functions

- DSMatrix ()

  Default constructor.
- DSMatrix (size_t dim)

  Constructor that for a symmetric matrix with given number of r‡qows.
- 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 ofthe 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 a*x and add result to y.*
- void MultAdd (T_ a, const Vect< T_ > &x, Vect< T_ > &y) const
  *Multiply matrix by vector a*x and add to y.*
- void Mult (const Vect< T_ > &x, Vect< T_ > &y) const
  Multiply matrix by vector x and save result in y.
- void TMult (const Vect< T_ > &x, Vect< T_ > &y) const
  Multiply transpose of matrix by vector x and add result in y.
- void Axpy (T_ a, const DSMatrix< 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 solve (Vect< T_ > &b, bool fact=true)

Solve linear system.

- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)

  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.

7.15.1 Detailed Description

template<class T_>class OFELI::DSMatrix< T_ >

To handle symmetric dense matrices.

This class enables storing and manipulating symmetric dense matrices.

Template Parameters

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

Author

Rachid Touzani

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7.15.2 Constructor & Destructor Documentation

DSMatrix (size_t *dim*)

Constructor that for a symmetric matrix with given number of r‡qows.

Parameters

in	*dim*	Number of rows

DSMatrix (const DSMatrix< T_ > & *m*)

Copy Constructor.

Parameters

in	*m*	DSMatrix instance to copy

DSMatrix (Mesh & *mesh*, size_t *dof* = 0, int *is_diagonal* = false)

Constructor using mesh to initialize matrix.

Parameters

in	*mesh*	Mesh 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.
in	*is_diagonal*	Boolean argument to say is the matrix is actually a diagonal matrix or not.

7.15.3 Member Function Documentation

void setSize (size_t *dim*)

Set size (number of rows) of matrix.

Parameters

in	*dim*	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*	row index
in	*j*	column index
in	*val*	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	*j*	Index of column to extract
out	*v*	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	*j*	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*	Index of row to extract
out	*v*	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	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	row index to be assigned
in	v	Vect 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	j	column index to be assigned
in	v	Vect instance to copy

void setDiag (const T_ & *a*)

Set matrix as diagonal and assign its diagonal entries as a constant.

Parameters

in	a	Value to assign to all diagonal entries

void setDiag (const vector< T_ > & *d*)

Set matrix as diagonal and assign its diagonal entries.

Parameters

in	d	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 ofthe matrix.

Parameters

in	i	row index
in	j	column index

in	*val*	value to add to `a(i,j)`

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

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 Axpy (T_ *a*, const DSMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.

Parameters

in	a	Scalar to premultiply
in	m	Matrix by which a is multiplied. The result is added to current instance

void Axpy (T_ *a*, const Matrix< T_ > * *m*) [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

in	a	Scalar to premultiply
in	m	Matrix by which a is multiplied. The result is added to current instance

Implements Matrix< T_ >.

int solve (Vect< T_ > & *b*, bool *fact* = true) [virtual]

Solve linear system.

The matrix is factorized using the LDLt (Crout) decomposition. If this one is already factorized, no further factorization is performed. If the matrix has been modified the user has to refactorize it using the function setLDLt.

Parameters

in,out	b	Vect instance that contains right-hand side on input and solution on output.
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

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*, bool *fact* = `true`) `[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`	*b*	Vect instance that contains right-hand side.
`out`	*x*	Vect instance that contains solution
`in`	*fact*	Set true if matrix is to be factorized (Default value), false if not

Returns

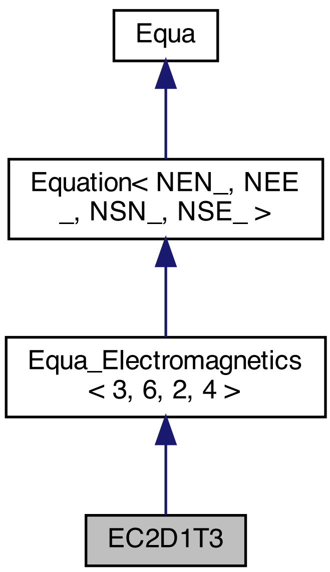
- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

Implements Matrix< T_ >.

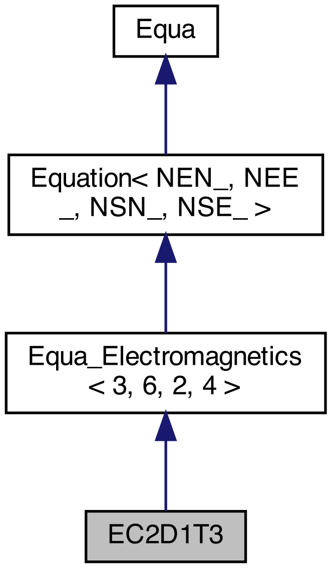
7.16 EC2D1T3 Class Reference

Eddy current problems in 2-D domains using solenoidal approximation.

Inheritance diagram for EC2D1T3:



Collaboration diagram for EC2D1T3:



Public Member Functions

- EC2D1T3 ()

  Default constructor.
- EC2D1T3 (Mesh &ms)

  Constructor using mesh.
- EC2D1T3 (Mesh &ms, Vect< real_t > &u)

  Constructor using mesh and solution vector.
- ~EC2D1T3 ()

  Destructor.
- void setData (real_t omega, real_t volt)

  Define data for equation.
- void build ()

  Build the linear system of equations.
- void Magnetic (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.
- void IntegMF (real_t &vr, real_t &vi)

  Add element integral contribution.

- void IntegND (const Vect< real_t > &h, real_t &vr, real_t &vi)

  Compute integral of normal derivative on edge.
- real_t VacuumArea ()

  Add contribution to vacuum area calculation.

Additional Inherited Members

7.16.1 Detailed Description

Eddy current problems in 2-D domains using solenoidal approximation.

Builds finite element arrays for time harmonic eddy current problems in 2-D domains with solenoidal configurations (Magnetic field has only one nonzero component). Magnetic field is constant in the vacuum, and then zero in the outer vacuum.

Uses 3-Node triangles.

The unknown is the time-harmonic magnetic induction (complex valued) but stored in 2-degree of freedom real-valued vector. Therefore, mesh must be defined with 2 degrees of freedom per node

Author

Rachid Touzani

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7.16.2 Constructor & Destructor Documentation

EC2D1T3 (Mesh & *ms*)

Constructor using mesh.

Parameters

in	*ms*	Mesh instance

EC2D1T3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and solution vector.

Parameters

in	*ms*	Mesh instance
in,out	*u*	Reference to solution vector instance

7.16.3 Member Function Documentation

void setData (real_t *omega*, real_t *volt*)

Define data for equation.

Parameters

in	*omega*	Angular frequency
in	*volt*	Voltage

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 Magnetic (real_t *coef* = `1.`)

Add magnetic contribution to matrix.

Parameters

in	*coef*	Coefficient to multiply by [Default: `1`]

void Electric (real_t *coef* = `1.`)

Add electric contribution to matrix.

Parameters

in	*coef*	Coefficient to multiply by [Default: `1`]

void IntegND (const Vect< real_t > & *h*, real_t & *vr*, real_t & *vi*)

Compute integral of normal derivative on edge.

Parameters

in	*h*	Vect instance containing magnetic field at nodes
in	*vr*	Real part of the integral
in	*vi*	Imaginary part of the integral

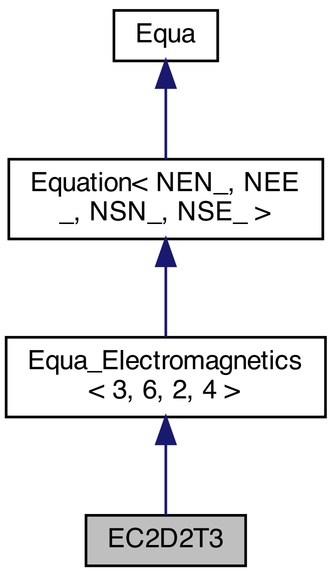
Note

This member function is to be called within each element, it detects boundary sides as the ones with nonzero code

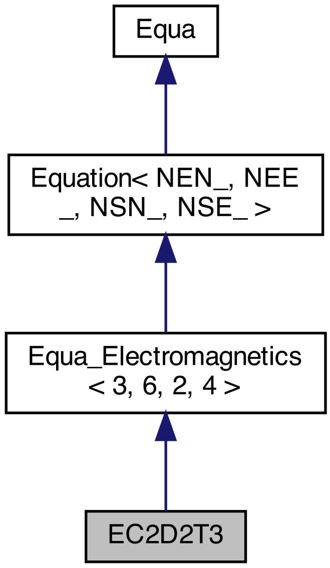
7.17 EC2D2T3 Class Reference

Eddy current problems in 2-D domains using transversal approximation.

Inheritance diagram for EC2D2T3:



Collaboration diagram for EC2D2T3:



Public Member Functions

- EC2D2T3 ()

  Default Constructor.
- EC2D2T3 (Mesh &ms)

  Constructor using mesh.
- EC2D2T3 (Mesh &ms, Vect< real_t > &u)

  Constructor using mesh and solution vector.
- 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 ()

  Compute Finite Element Diagonal Block.
- void BEBlocks (size_t n1, size_t n2, SpMatrix< real_t > &L, SpMatrix< real_t > &U, Sp←Matrix< real_t > &D)

  Compute boundary element blocks.
- complex_t Constant (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.

Additional Inherited Members

7.17.1 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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7.17.2 Constructor & Destructor Documentation

EC2D2T3 (Mesh & *ms*)

Constructor using mesh.

Parameters

`in`	*ms*	Mesh instance

EC2D2T3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and solution vector.

Parameters

`in`	*ms*	Mesh instance
`in,out`	*u*	Vect instance containing solution

7.18 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 ().

7.18.1 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

Copyright

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7.18.2 Constructor & Destructor Documentation

Edge ( )

Default Constructor.

Initializes data to zero

Edge (size_t *label*)

Constructor with label.

Define an edge by giving its `label`

7.18.3 Member Function Documentation

void DOF (size_t *i*, size_t *dof*)

Define label of DOF.

Parameters

`in`	*i*	DOF index
`in`	*dof*	Its label

void setDOF (size_t & *first_dof*, size_t *nb_dof*)

Define number of DOF.

Parameters

`in,out`	*first_dof*	Label of the first DOF in input that is actualized
`in`	*nb_dof*	Number of DOF

void setCode (size_t *dof*, int *code*)

Assign code `code` to DOF number `dof`.

Parameters

`in`	*dof*	index of dof for assignment.
`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`

7.19 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)

7.19.1 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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7.19.2 Member Function Documentation

void selectCode (int *code*, int *dof* = *1*)

Select edges having a given code for a given degree of freedom.
Parameters

in	*code*	Code that edges share
in	*dof*	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	*code*	Code of edges to exclude
in	*dof*	Degree of Freedom label [Default: 1]

7.20 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 (Equa &eq, bool lumped=true)

Consrtuctor 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 (Equa &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.

7.20.1 Detailed Description

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.

Author

Rachid Touzani

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7.20.2 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 = aMx`, where `K` and `M` are referred to as stiffness and mass matrix.

EigenProblemSolver (SkSMatrix< real_t > & *K*, Vect< real_t > & *M*, int *n* = 0)

Constructor for Symmetric Skyline Matrices.

Parameters

in	*K*	"Stiffness" matrix
in	*M*	Diagonal "Mass" matrix stored as a Vect instance
in	*n*	Number of eigenvalues to extract. By default all eigenvalues are computed.

Note

The generalized eigenvalue problem is defined by `Kx = aMx`, 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*	Matrix 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 (Equa & *eq*, bool *lumped* = `true`)

Consrtuctor using partial differential equation.
The used equation class must have been constructed using the Mesh instance
Parameters

in	*eq*	Reference to equation instance
in	*lumped*	Mass matrix is lumped (*true*) or not (*false*) [Default: `true`]

7.20.3 Member Function Documentation

void setMatrix (SkSMatrix< real_t > & *K*, SkSMatrix< real_t > & *M*)

Set matrix instances (Symmetric matrices).
This function is to be used when the default constructor is applied. Case where the mass matrix is consistent.
Parameters

in	*K*	Stiffness matrix instance
in	*M*	Mass matrix instance

void setMatrix (SkSMatrix< real_t > & *K*, Vect< real_t > & *M*)

Set matrix instances (Symmetric matrices).
This function is to be used when the default constructor is applied. Case where the mass matrix is (lumped) diagonal and stored in a vector.
Parameters

in	*K*	Stiffness matrix instance
in	*M*	Mass matrix instance where diagonal terms are stored as a vector.

void setMatrix (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	*K*	Stiffness matrix instance

void setPDE (Equa & *eq*, bool *lumped* = `true`)

Define partial differential equation to solve.
The used equation class must have been constructed using the Mesh instance

Parameters

in	*eq*	Reference to equation instance
in	*lumped*	Mass matrix is lumped (*true*) or not (*false*) [Default: `true`]

int run (int *nb* = *0*)

Run the eigenproblem solver.
Parameters

in	*nb*	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	*el*	Reference to Element class
in	*eK*	Pointer to element stiffness (or assimilated) matrix
in	*eM*	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	*sd*	Reference to Side class
in	*sK*	Pointer to side stiffness

int runSubSpace (size_t *nb_eigv*, size_t *ss_dim* = *0*)

Run the subspace iteration solver.
This function rune the Bathe subspace iteration method.
Parameters

in	*nb_eigv*	Number of eigenvalues to be extracted
in	*ss_dim*	Subspace dimension. Must be at least equal to the number eigenvalues to seek. [Default: `nb_eigv`]

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	*dim*	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	*eps*	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	*nb_found*	number of eigenvalues actually found
out	*nb_lost*	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.

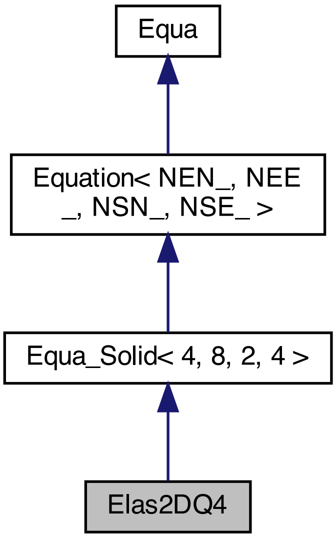
Parameters

in	*n*	Label of eigenvector (They are stored in ascending order of eigenvalues)
in,out	*v*	Vect instance where the eigenvector is stored.

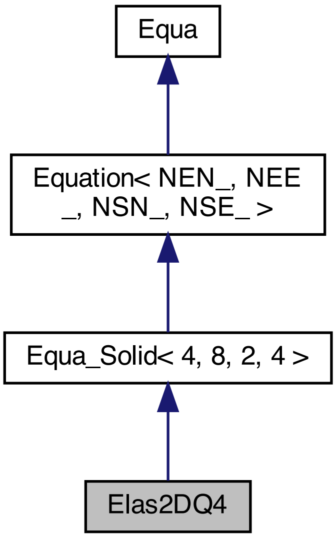
7.21 Elas2DQ4 Class Reference

To build element equations for 2-D linearized elasticity using 4-node quadrilaterals.

Inheritance diagram for Elas2DQ4:



Collaboration diagram for Elas2DQ4:



Public Member Functions

- Elas2DQ4 ()

  Default Constructor.
- Elas2DQ4 (Mesh &ms)

  Constructor using Mesh instance.
- Elas2DQ4 (Mesh &ms, Vect< real_t > &u)

  Constructor using Mesh instance and solution vector.
- ∼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 LMass (real_t coef=1.)

  Add element lumped mass contribution to element matrix 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 element matrix after multiplication by `coef` [Default: 1].
- void Dilatation (real_t coef=1.)

  Add element dilatational contribution to element matrix after multiplication by `coef` [Default: 1].
- void BodyRHS (const Vect< real_t > &f)

  Add body right-hand side term to right hand side.
- void BodyRHS ()

  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 BoundaryRHS ()

  Add boundary right-hand side term to right hand side.
- void Strain (Vect< real_t > &eps)

  Calculate strains at element barycenters.
- void Stress (Vect< real_t > &st, Vect< real_t > &vm)

  Calculate principal stresses and Von-Mises stress at element barycenter.
- void Stress (Vect< real_t > &sigma, Vect< real_t > &s, Vect< real_t > &st)

  Calculate principal stresses and Von-Mises stress at element barycenter.

Additional Inherited Members

7.21.1 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.

7.21.2 Constructor & Destructor Documentation

Elas2DQ4 ( )

Default Constructor.

Constructs an empty equation.

Elas2DQ4 (Mesh & *ms*)

Constructor using Mesh instance.
Parameters

in	*ms*	Reference to Mesh instance

Elas2DQ4 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh instance and solution vector.
Parameters

in	*ms*	Reference to Mesh instance
in,out	*u*	Solution vector

7.21.3 Member Function Documentation

void PlaneStrain (real_t *E*, real_t *nu*)

Set plane strain hypothesis by giving values of Young's modulus and Poisson ratio.
Parameters

in	*E*	Young's modulus
in	*nu*	Poisson ratio

void PlaneStress (real_t *E*, real_t *nu*)

Set plane stress hypothesis by giving values of Young's modulus and Poisson ratio.
Parameters

in	*E*	Young's modulus
in	*nu*	Poisson ratio

void BodyRHS (const Vect< real_t > & *f*)

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

Parameters

in	f	Vector containing source at nodes (DOF by DOF).

void BoundaryRHS (const Vect< real_t > & *f*)

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

Parameters

in	f	Vector containing source at nodes (DOF by DOF).

void Strain (Vect< real_t > & *eps*)

Calculate strains at element barycenters.

Parameters

out	*eps*	Vector containing strains in elements

Remarks

> The instance of Elas2DQ4 must have been constructed using the constructor with Mesh instance and solution vector

void Stress (Vect< real_t > & *st*, Vect< real_t > & *vm*)

Calculate principal stresses and Von-Mises stress at element barycenter.

Parameters

out	*st*	Vector containing principal stresses in elements
out	*vm*	Vector containing Von-Mises stresses in elements

Remarks

> The instance of Elas2DQ4 must have been constructed using the constructor with Mesh instance and solution vector

void Stress (Vect< real_t > & *sigma*, Vect< real_t > & *s*, Vect< real_t > & *st*)

Calculate principal stresses and Von-Mises stress at element barycenter.

Parameters

out	*sigma*	Vector containing principal stresses in elements
out	*s*	Vector containing principal stresses in elements
out	*st*	Value of Von-Mises stress in elements

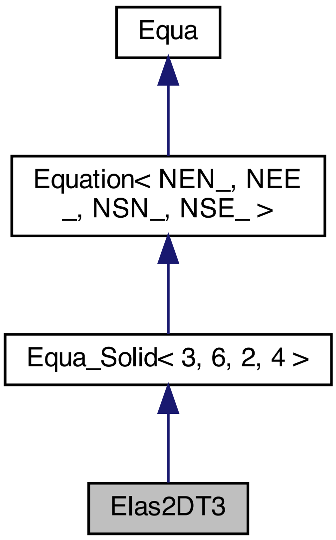
Remarks

> The instance of Elas2DQ4 must have been constructed using the constructor with Mesh instance and solution vector

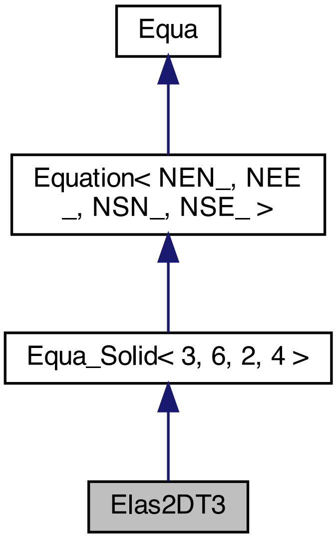
7.22 Elas2DT3 Class Reference

To build element equations for 2-D linearized elasticity using 3-node triangles.

Inheritance diagram for Elas2DT3:



Collaboration diagram for Elas2DT3:



Public Member Functions

- Elas2DT3 ()

  Default Constructor.
- Elas2DT3 (Mesh &ms)

  Constructor using Mesh data.
- Elas2DT3 (Mesh &ms, Vect< real_t > &u)

  Constructor using Mesh data and solution vector.
- ∼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 LMass (real_t coef=1.)

  Add element lumped mass contribution to element matrix after multiplication by `coef`
- void Mass (real_t coef=1.)

Add element consistent mass contribution to element matrix after multiplication by `coef`

- void Deviator (real_t coef=1.)

  Add element deviatoric matrix to element matrix after multiplication by `coef`
- void Dilatation (real_t coef=1.)

  Add element dilatational contribution to element matrix after multiplication by `coef`
- void BodyRHS (const Vect< real_t > &f)

  Add body right-hand side term to right hand side.
- void BodyRHS ()

  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 BoundaryRHS ()

  Add boundary right-hand side term to right hand side.
- int Contact (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, Vect< 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).

Additional Inherited Members

7.22.1 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.

7.22.2 Constructor & Destructor Documentation

Elas2DT3 ( )

Default Constructor.

Constructs an empty equation.

Elas2DT3 (Mesh & *ms*)

Constructor using Mesh data.

Parameters

in	*ms*	Mesh instance

Elas2DT3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using Mesh data and solution vector.
Parameters

in	*ms*	Mesh instance
in,out	*u*	Reference to solution vector

7.22.3 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 LMass (real_t *coef* = 1.) `[virtual]`

Add element lumped mass contribution to element matrix after multiplication by `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Solid< 3, 6, 2, 4 >.

void Mass (real_t *coef* = 1.) `[virtual]`

Add element consistent mass contribution to element matrix after multiplication by `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Solid< 3, 6, 2, 4 >.

void Deviator (real_t *coef* = 1.) `[virtual]`

Add element deviatoric matrix to element matrix after multiplication by `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Solid< 3, 6, 2, 4 >.

void Dilatation (real_t *coef* = 1.) `[virtual]`

Add element dilatational contribution to element matrix after multiplication by `coef`
Parameters

in	*coef*	Coefficient to multiply by added term [Default: 1].

Reimplemented from Equa_Solid< 3, 6, 2, 4 >.

void BodyRHS (const Vect< real_t > & *f*)

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

Parameters

in	*f*	Vector containing source at nodes (DOF by DOF)

void BoundaryRHS (const Vect< real_t > & *f*)

Add boundary right-hand side term to right hand side.
Parameters

in	*f*	Vect instance that contains constant traction to impose to side.

int Contact (real_t *coef* = `1.e07`)

Penalty Signorini contact side contribution to matrix and right-hand side.
Parameters

in	*coef*	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	*r*	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.
Parameters

out	*eps*	vector of strains in elements

void Stress (Vect< real_t > & *s*, Vect< real_t > & *vm*)

Calculate principal stresses and Von-Mises stress in element.

Parameters

out	*s*	vector of principal stresses in elements
out	*vm*	Von-Mises stresses in elements 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.

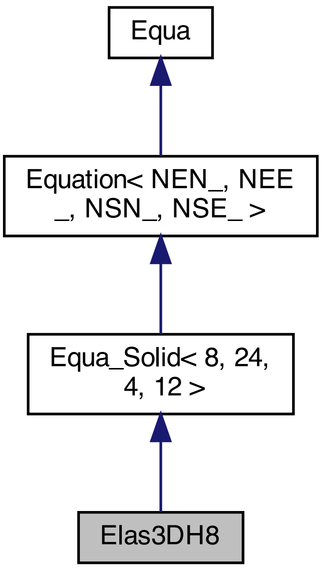
Parameters

in	*coef*	Value of penalty parameter [Default: `1.e20`]

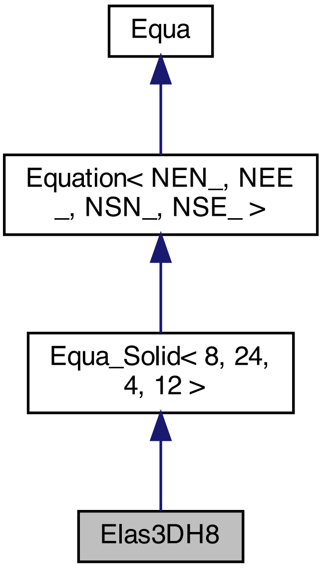
7.23 Elas3DH8 Class Reference

To build element equations for 3-D linearized elasticity using 8-node hexahedra.

Inheritance diagram for Elas3DH8:



Collaboration diagram for Elas3DH8:



Public Member Functions

- Elas3DH8 ()

  Default Constructor.
- Elas3DH8 (Mesh &ms)

  Constructor using Mesh instance.
- ~Elas3DH8 ()

  Destructor.
- void LMass (real_t coef=1.)

  Add element lumped mass contribution to element matrix after multiplication by coef.
- void Mass (real_t coef=1.)

  Add element lumped mass contribution to element matrix and right-hand side after multiplication by coef.
- void Deviator (real_t coef=1.)

  Add element deviatoric matrix to element matrix after multiplication by coef.
- void Dilatation (real_t coef=1.)

  Add element dilatational contribution to element matrix after multiplication by coef.
- void BoundaryRHS (const Vect< real_t > &f)

  Add boundary right-hand side term to right hand side.
- void BoundaryRHS ()

  Add boundary right-hand side term to right hand side.
- void BodyRHS (const Vect< real_t > &f)

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

- void BodyRHS ()

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

Additional Inherited Members

7.23.1 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.

7.23.2 Constructor & Destructor Documentation

Elas3DH8 ( )

Default Constructor.

Constructs an empty equation.

Elas3DH8 (Mesh & *ms*)

Constructor using Mesh instance.

Parameters

`in`	*ms*	Reference to Mesh instance

7.23.3 Member Function Documentation

void BoundaryRHS (const Vect< real_t > & *f*)

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

Parameters

`in`	*f*	Vector containing traction (boundary force) at sides

void BodyRHS (const Vect< real_t > & *f*)

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

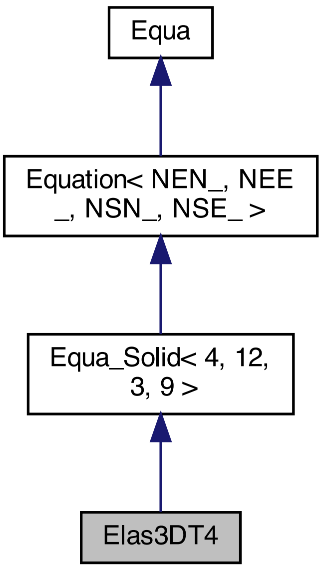
Parameters

`in`	*f*	Vector containing source at nodes (DOF by DOF).

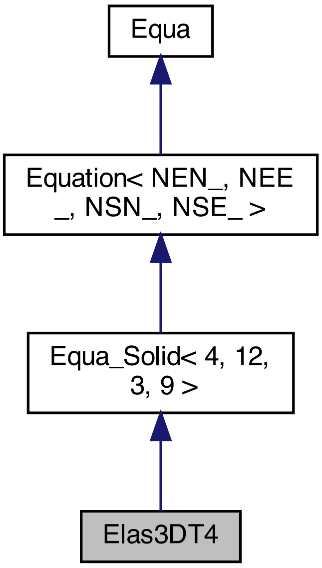
7.24 Elas3DT4 Class Reference

To build element equations for 3-D linearized elasticity using 4-node tetrahedra.

Inheritance diagram for Elas3DT4:



Collaboration diagram for Elas3DT4:



Public Member Functions

- Elas3DT4 ()

  Default Constructor.
- Elas3DT4 (Mesh &ms)

  Constructor using a Mesh instance.
- Elas3DT4 (Mesh &ms, Vect< real_t > &u)

  Constructor using a Mesh instance and solution vector.
- ~Elas3DT4 ()

  Destructor.
- void Media (real_t E, real_t nu, real_t rho)

  Set Media properties.
- void LMass (real_t coef=1)

  Add element lumped mass contribution to element matrix after multiplication by coef.
- void Deviator (real_t coef=1.)

  Add element deviatoric matrix to element matrix after multiplication by coef.
- void Dilatation (real_t coef=1.)

  Add element dilatational contribution to left-hand side after multiplication by coef.
- void BodyRHS (const Vect< real_t > &f)

  Add body right-hand side term to right hand side.
- void BodyRHS ()

  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 BoundaryRHS ()

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

Additional Inherited Members

7.24.1 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.

7.24.2 Constructor & Destructor Documentation

Elas3DT4 (Mesh & *ms*)

Constructor using a Mesh instance.

Parameters

in	*ms*	Reference to Mesh instance

Elas3DT4 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using a Mesh instance and solution vector.

Parameters

in	*ms*	Reference to Mesh instance
in,out	*u*	Reference to solution vector

7.24.3 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 (const Vect< real_t > & *f*)

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

Parameters

in	*f*	Vect instance containing source at nodes (DOF by DOF).

void BoundaryRHS (const Vect< real_t > & *f*)

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

Parameters

in	*f*	Vect instance that contains constant traction to impose to side.

7.25 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 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 neigboring elements.
- real_t getMeasure () const

  Return measure of element.
- Point< real_t > getCenter () const

  Return coordinates of center 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.

7.25.1 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:

Shape Shape name Dimension Min. number of nodes Line line 2 2 Triangle tria 2 3 Quadrilateral quad 2 4 Tetrahedron tetra 3 4 Pentahedron penta 3 6 Hexahedron hexa 3 8

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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7.25.2 Constructor & Destructor Documentation

Element (size_t *label*, const string & *shape*)

Constructor initializing label, shape of element.

Parameters

in	*label*	Label to assign to element.
in	*shape*	Shape of element (See class description).

Element (size_t *label*, int *shape*)

Constructor initializing label, shape of element.

Parameters

in	*label*	Label to assign to element.
in	*shape*	Shape of element (See enum ElementShape in Mesh)

Element (size_t *label*, const string & *shape*, int *c*)

Constructor initializing label, shape and code of element.

Parameters

in	*label*	Label to assign to element.
in	*shape*	Shape of element (See class description).
in	*c*	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	*label*	Label to assign to element.
in	*shape*	Shape of element (See enum ElementShape in Mesh).
in	*c*	Code to assign to element (useful for media properties).

7.25.3 Member Function Documentation

void setLabel (size_t *i*)

Define label of element.

Parameters

in	*i*	Label to assign to element

void setCode (int *c*)

Define code of element.
Parameters

in	*c*	Code to assign to element.

void Add (Node ∗ *node*)

Insert a node at end of list of nodes of element.
Parameters

in	*node*	Pointer to Node instance.

void Add (Node ∗ *node*, int *n*)

Insert a node and set its local node number.
Parameters

	node	[in] Pointer to Node instance
in	*n*	Element node number to assign

void Replace (size_t *label*, Node ∗ *node*)

Replace a node at a given local label.
Parameters

in	*label*	Node to replace.
in	*node*	Pointer to Node instance to copy to current instance.

void Replace (size_t *label*, Side ∗ *side*)

Replace a side at a given local label.
Parameters

in	*label*	Side to replace.
in	*side*	Pointer to Side instance to copy to current instance.

void Add (Side ∗ *sd*)

Assign Side to Element.
Parameters

in	*sd*	Pointer to Side instance.

void Add (Side ∗ *sd*, int *k*)

Assign Side to Element with assigned local label.

Parameters

in	*sd*	Pointer to Side instance.
in	*k*	Local label.

void Add (Element * *el*)

Add a neighbor element.
Parameters

in	*el*	Pointer to Element instance

void set (Element * *el*, int *n*)

Add a neighbor element and set its label.
Parameters

in	*el*	Pointer to Element instance
in	*n*	Neighbor element number to assign

void setDOF (size_t *i*, size_t *dof*)

Define label of DOF.
Parameters

in	*i*	Index of DOF.
in	*dof*	Label of DOF to assign.

void setCode (size_t *dof*, int *code*)

Assign code to a DOF.
Parameters

in	*dof*	Index of dof for assignment.
in	*code*	Code to assign.

Node* operator() (size_t *i*) const

Operator ().
Return pointer to node of local label `i`.

int Contains (const Node * *nd*) const

Say if element contains given node.
This function tests if the element contains a node with the same pointer at the sought one
Parameters

in	*nd*	Pointer to Node 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	*nd*	Reference to Node 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	*sd*	Pointer to Side 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	*sd*	Reference to Side 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*	Index of element to look for.

Note

This method returns valid information only if the Mesh member function Mesh::getElementNeighborElements() has been called before.

size_t getNbNeigElements ( ) const

Return number of neigboring elements.

Note

This method returns valid information only if the Mesh member function Mesh::getElementNeighborElements() has been called before.

real_t getMeasure ( ) const

Return measure of element.

This member function returns length, area or volume of element. In case of quadrilaterals and hexahedrals it returns determinant of Jacobian of mapping between reference and actual element

Point<real_t> getUnitNormal (size_t *i*) const

Return outward unit normal to i-th side of element.

Sides are ordered [node_1,node_2], [node_2,node_3], ...

bool isOnBoundary ( ) const

Say if current element is a boundary element or not.

Note

this information is available only if boundary elements were determined i.e. if member function Mesh::getBoundarySides or Mesh::getAllSides has been invoked before.

Node∗ operator() (size_t *i*)

Operator ().

Return pointer to node of local label `i`.

int setSide (size_t *n*, size_t ∗ *nd*)

Initialize information on element sides.

This function is to be used to initialize loops over sides.

Parameters

`in`	*n*	Label of side.
`in`	*nd*	Array of pointers to nodes of the side (`nd[0]`, `nd[1]`, `...` point to first, second nodes, ...

void setChild (Element ∗ *el*)

Assign element as child of current one and assign current element as father This function is principally used when refining is invoked (e.g. for mesh adaption)

Parameters

`in`	*el*	Pointer to element to assign

size_t IsIn (const Node ∗ *nd*)

Check if a given node belongs to current element.

Parameters

`in`	*nd*	Pointer to node to locate

Returns

local label of node if this one is found, 0 otherwise

7.26 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)

7.26.1 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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7.26.2 Member Function Documentation

void unselectCode (int *code*)

Unselect elements having a given code.

Parameters

in	*code*	Code of elements to exclude

void selectLevel (int *level*)

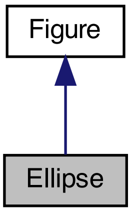
Select elements having a given level.
Parameters

in	*level*	Level of elements to select

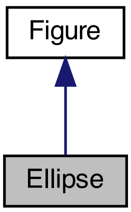
Elements having a given level (for mesh adaption) are selected in a list

7.27 Ellipse Class Reference

To store and treat an ellipsoidal figure.
Inheritance diagram for Ellipse:



Collaboration 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 ∗=

7.27.1 Detailed Description

To store and treat an ellipsoidal figure.

7.27.2 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	*c*	Coordinates of center
in	*a*	Semimajor axis
in	*b*	Semiminor axis
in	*code*	Code to assign to the generated figure [Default: 1]

7.27.3 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	*p*	Point<double> instance

Reimplemented from Figure.

Ellipse& operator+= (Point< real_t > *a*)

Operator +=
Translate ellipse by a vector `a`
Parameters

in	*a*	Vector defining the translation

Ellipse& operator+= (real_t *a*)

Operator ∗=
Scale ellipse by a factor `a`

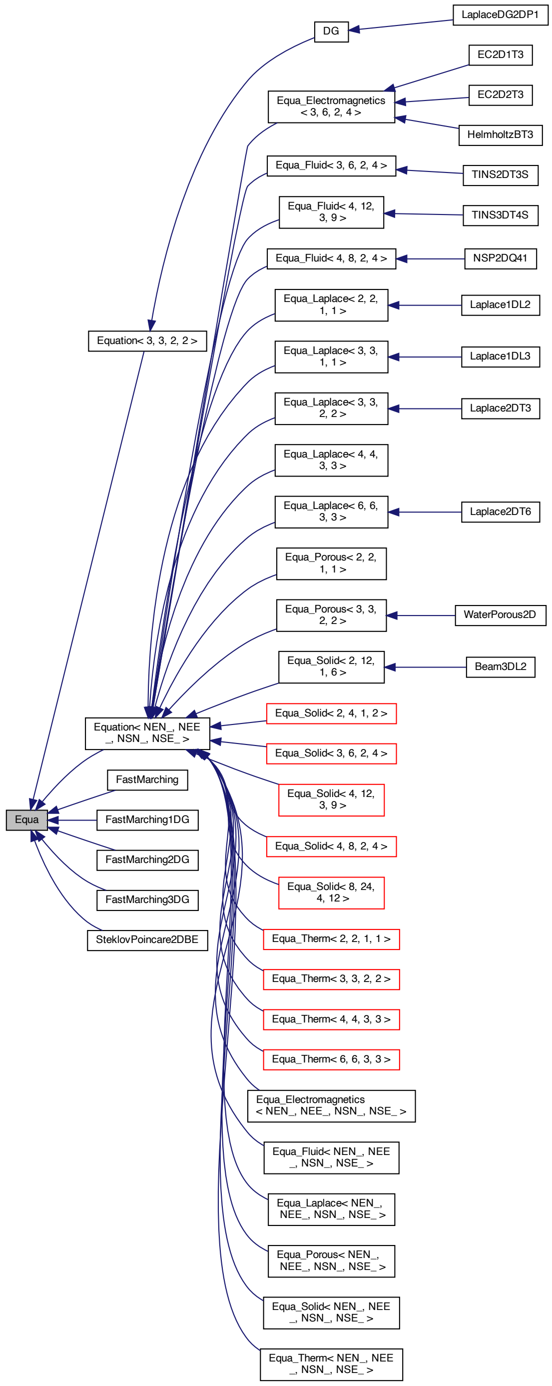
Parameters

in	*a*	Scaling value

7.28 Equa Class Reference

Mother abstract class to describe equation.

Inheritance diagram for Equa:



Public Member Functions

- Equa ()

    Default constructor.

- virtual ~Equa ()

  Destructor.
- 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.
- Matrix< real_t > * getMatrix () const

  Return pointer to matrix.
- void setSolver (Iteration ls, Preconditioner pc=IDENT_PREC)

  Choose solver for the linear system.
- void setLinearSolver (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.

7.28.1 Detailed Description

Mother abstract class to describe equation.

Author

Rachid Touzani

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7.28.2 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	*ls*	Solver of the linear system. To choose among the enumerated values: `DIRECT_SOLVER`, `CG_SOLVER`, `GMRES_SOLVER` • `DIRECT_SOLVER`, Use a facorization solver [default] • `CG_SOLVER`, Conjugate Gradient iterative solver • `CGS_SOLVER`, Squared Conjugate Gradient iterative solver • `BICG_SOLVER`, BiConjugate Gradient iterative solver • `BICG_STAB_SOLVER`, BiConjugate Gradient Stabilized iterative solver • `GMRES_SOLVER`, GMRES iterative solver • `QMR_SOLVER`, QMR iterative solver
in	*pc*	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: • `IDENT_PREC`, Identity preconditioner (no preconditioning [default]) • `DIAG_PREC`, Diagonal preconditioner • `ILU_PREC`, Incomplete LU factorization preconditioner

void setLinearSolver (Iteration *ls*, Preconditioner *pc* = IDENT_PREC)

Choose solver for the linear system.
Parameters

in	*ls*	Solver of the linear system. To choose among the enumerated values: `DIRECT_SOLVER`, `CG_SOLVER`, `GMRES_SOLVER` • `DIRECT_SOLVER`, Use a facorization solver [default] • `CG_SOLVER`, Conjugate Gradient iterative solver • `CGS_SOLVER`, Squared Conjugate Gradient iterative solver • `BICG_SOLVER`, BiConjugate Gradient iterative solver • `BICG_STAB_SOLVER`, BiConjugate Gradient Stabilized iterative solver • `GMRES_SOLVER`, GMRES iterative solver • `QMR_SOLVER`, QMR iterative solver

in	*pc*	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: • `IDENT_PREC`, Identity preconditioner (no preconditioning [default]) • `DIAG_PREC`, Diagonal preconditioner • `ILU_PREC`, Incomplete LU factorization preconditioner

void setMatrixType (int *t*)

Choose type of matrix.

Parameters

in	*t*	Type of the used matrix. To choose among the enumerated values: `SKYLINE`, `SPARSE`, `DIAGONAL` `TRIDIAGONAL`, `SYMMETRIC`, `U`↩ `NSYMMETRIC`, `IDENTITY`

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.

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< real_t > & *b*, Vect< real_t > & *x*)

Solve the linear system with given right-hand side.

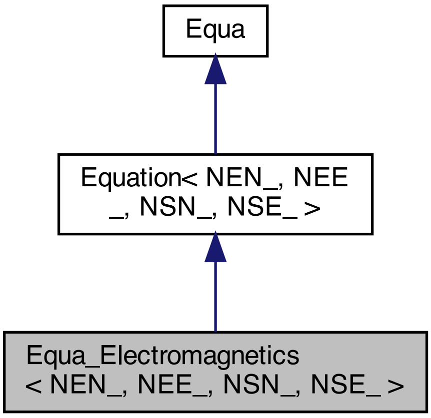
Parameters

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

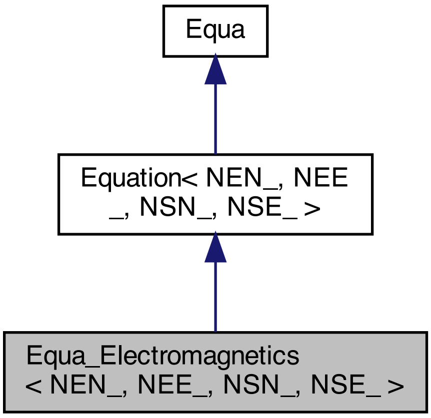
7.29 Equa_Electromagnetics< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for Electromagnetics Equation classes.

Inheritance diagram for Equa_Electromagnetics< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Electromagnetics< NEN_, NEE_, NSN_, NSE_ >:



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 setMaterial ()

  Set material properties.

Additional Inherited Members

7.29.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Electromagnetics< NEN_, NEE_, NSN_, NSE_ >

Abstract class for Electromagnetics Equation classes.

Template Parameters

<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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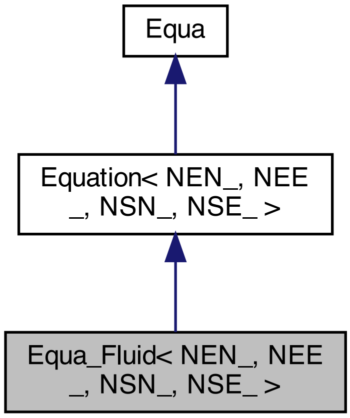
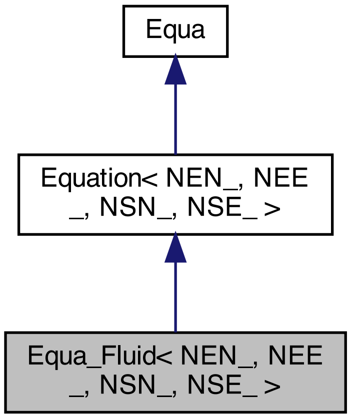
7.30 Equa_Fluid< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for Fluid Dynamics Equation classes.

Inheritance diagram for Equa_Fluid< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Fluid< NEN_, NEE_, NSN_, NSE_ >:



Public Member Functions

- Equa_Fluid ()

  Default constructor.
- virtual ~Equa_Fluid ()

  Destructor.

- void Reynolds (const real_t &Re)

  Set Reynolds number.
- 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.

7.30.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Fluid< NE↩ N_, 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

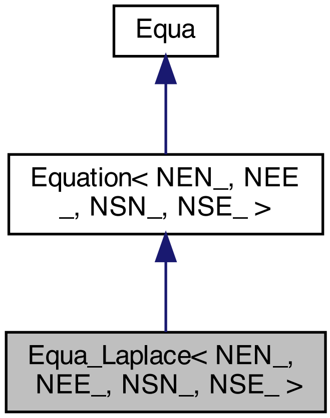
Equa_Fluid ( )

Default constructor.
Constructs an empty equation.

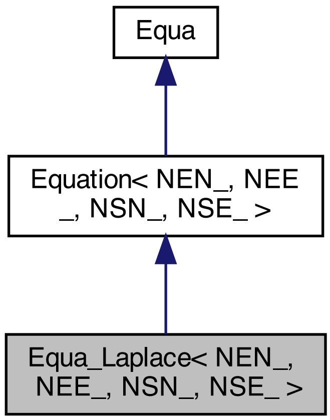
7.31 Equa_Laplace< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for classes about the Laplace equation.

Inheritance diagram for Equa_Laplace< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Laplace< NEN_, NEE_, NSN_, NSE_ >:



Public Member Functions

- Equa_Laplace ()

  Default constructor.
- virtual ~Equa_Laplace ()

  Destructor.

- virtual void LHS ()

    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.
- 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.

7.31.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Laplace< N↩ EN_, NEE_, NSN_, NSE_ >

Abstract class for classes about the Laplace equation.
Template Parameters

*T_*	Data type (real_t, float, complex<real_t>, ...)
*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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7.31.2 Constructor & Destructor Documentation

Equa_Laplace ( )

Default constructor.
Constructs an empty equation.

7.31.3 Member Function Documentation

virtual void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

Add body source term to right-hand side.
Parameters

in	*f*	Vector containing the source given function at mesh nodes

Reimplemented in Laplace2DT3, Laplace1DL2, Laplace1DL3, and Laplace2DT6.

virtual void BoundaryRHS (const Vect< real_t > & *h*) `[virtual]`

Add boundary source term to right-hand side.
Parameters

in	*h*	Vector containing the source given function at mesh nodes

Reimplemented in Laplace2DT3, Laplace1DL2, Laplace1DL3, and Laplace2DT6.

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.

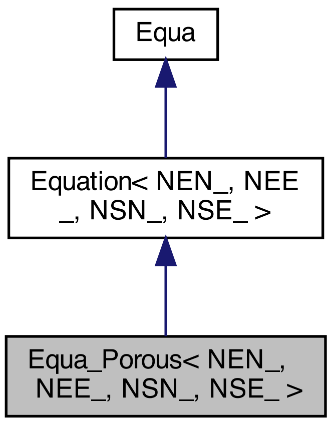
void build (EigenProblemSolver & *e*)

Build the linear system for an eigenvalue problem.
Parameters

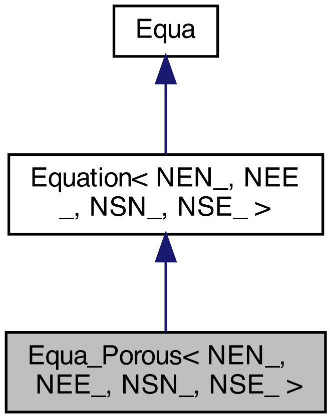
in	*e*	Reference to used EigenProblemSolver instance

7.32 Equa_Porous< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for Porous Media Finite Element classes.
Inheritance diagram for Equa_Porous< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Porous< 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)

  Add source right-hand side term to right-hand side.
- virtual void BoundaryRHS (const Vect< real_t > &sf)

  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.

Protected Member Functions

- void setMaterial ()

  Set material properties.

7.32.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Porous< 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*) `[virtual]`

Add source right-hand side term to right-hand side.
Parameters

`in`	*bf*	Vector containing source at nodes.

Reimplemented in WaterPorous2D.

virtual void BoundaryRHS (const Vect< real_t > & *sf*) `[virtual]`

Add boundary right-hand side term to right-hand side.
Parameters

`in`	*sf*	Vector containing source at nodes.

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 TimeStepping instance

void build (EigenProblemSolver & *e*)

Build the linear system for an eigenvalue problem.

Parameters

`in`	*e*	Reference to used EigenProblemSolver instance

int run ( )

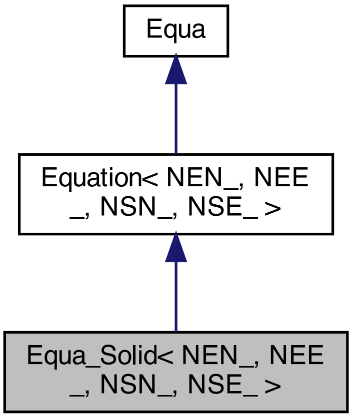
Run the equation.

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.

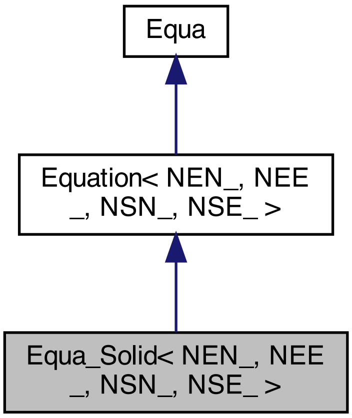
7.33 Equa_Solid< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for Solid Mechanics Finite Element classes.

Inheritance diagram for Equa_Solid< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Solid< NEN_, NEE_, NSN_, NSE_ >:



Public Member Functions

- Equa_Solid ()

  Default constructor.
- virtual ~Equa_Solid ()

  Destructor.

- virtual void LMass (real_t coef=1)

  Add lumped mass contribution to left-hand side.
- virtual void Mass (real_t coef=1)

  Add consistent mass contribution to left-hand side.
- 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 Stiffness (real_t coef=1)

  Add stiffness matrix to left-hand side taking into account time integration scheme, after multiplication by `coef` *[Default: 1].*
- void setInput (EqDataType opt, Vect< real_t > &u)

  Set specific input data to solid mechanics.

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.

7.33.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Solid< NEN_, NEE_, NSN_, NSE_ >

Abstract class for Solid Mechanics Finite Element classes.
Template Parameters

<NEN>	Number of element nodes
<NEE_>	Number of element equations
<NSN_>	Number of side nodes
<NSE_>	Number of side equations

7.33.2 Constructor & Destructor Documentation

Equa_Solid ( )

Default constructor.
Constructs an empty equation.

7.33.3 Member Function Documentation

virtual void LMass (real_t ***coef*** **=** *1* **)** `[virtual]`

Add lumped mass contribution to left-hand side.

Parameters

in	*coef*	coefficient to multiply by the matrix before adding [Default: 1]

Reimplemented in Beam3DL2, Elas2DT3, Elas2DQ4, Elas3DT4, Bar2DL2, and Elas3DH8.

virtual void Mass (real_t ***coef*** **=** *1* **)** `[virtual]`

Add consistent mass contribution to left-hand side.

Parameters

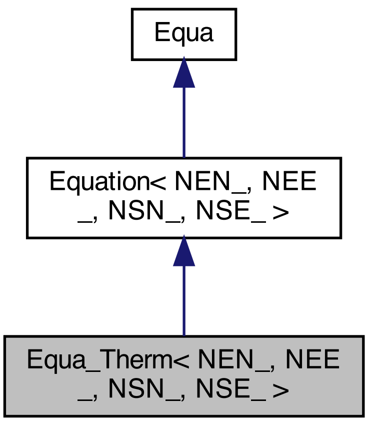
in	*coef*	coefficient to multiply by the matrix before adding [Default: 1]

Reimplemented in Beam3DL2, Elas2DT3, Elas2DQ4, Bar2DL2, and Elas3DH8.

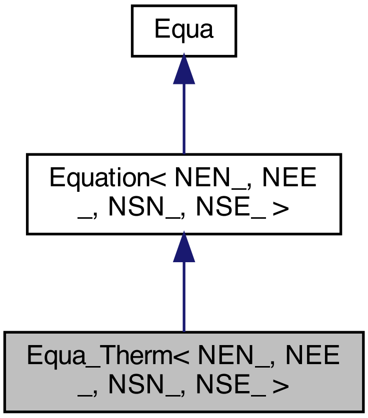
7.34 Equa_Therm< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for Heat transfer Finite Element classes.

Inheritance diagram for Equa_Therm< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equa_Therm< NEN_, NEE_, NSN_, NSE_ >:



Public Member Functions

- Equa_Therm ()

  Default constructor.
- virtual ~Equa_Therm ()

  Destructor.
- virtual void setStab ()

  Set stabilized formulation.
- virtual void LCapacity (real_t coef=1)

  Add lumped capacity contribution to element matrix.
- virtual void Capacity (real_t coef=1)

  Add consistent capacity contribution to left-hand side.
- virtual void Diffusion (real_t coef=1.)

  Add diffusion term to element matrix.
- virtual void Convection (real_t coef=1.)

  Add convection term to element matrix.
- virtual void BodyRHS (const Vect< real_t > &f)

  Add body right-hand side term to right-hand side.
- virtual void BoundaryRHS (const Vect< real_t > &f)

  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.

- void setRho (const real_t &rho)

  Set Density (constant)
- void setCp (const real_t &cp)

  Set Specific heat (constant)
- void setConductivity (const real_t &diff)

  Set (constant) thermal conductivity.

Protected Member Functions

- void setMaterial ()

  Set material properties.

7.34.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equa_Therm< N↩ EN_, NEE_, NSN_, NSE_ >

Abstract class for Heat transfer Finite Element classes.
Template Parameters

<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 Péclet number is large.
By default, no stabilization is used.

virtual void LCapacity (real_t *coef* = *1*) `[virtual]`

Add lumped capacity contribution to element matrix.
Parameters

in	*coef*	coefficient to multiply by the matrix before adding [Default: 1]

Reimplemented in DC2DT3, DC1DL2, DC3DT4, DC3DAT3, and DC2DT6.

virtual void Capacity (real_t *coef* = *1*) `[virtual]`

Add consistent capacity contribution to left-hand side.

Parameters

in	*coef*	coefficient to multiply by the matrix before adding [Default: 1]

Reimplemented in DC2DT3, DC1DL2, DC3DT4, DC3DAT3, and DC2DT6.

virtual void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

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

Parameters

in	*f*	Vector containing source at nodes.

Reimplemented in DC2DT3, DC3DT4, DC1DL2, DC2DT6, and DC3DAT3.

virtual void BoundaryRHS (const Vect< real_t > & *f*) `[virtual]`

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

Parameters

in	*f*	Vector containing source at nodes.

Reimplemented in DC2DT3, DC3DT4, DC2DT6, and DC3DAT3.

void build ( )

Build the linear system of equations.

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

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

void build (TimeStepping & *s*)

Build the linear system of equations.

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

- The choice of a steady state or transient analysis. By default, the analysis is stationary
- In the case of transient analysis, the choice of a time integration scheme and a lumped or consistent capacity matrix. If transient analysis is chosen, the lumped capacity matrix option is chosen by default, and the implicit Euler scheme is used by default for time integration.

Parameters

in	*s*	Reference to used TimeStepping instance

void build (EigenProblemSolver & *e*)

Build the linear system for an eigenvalue problem.

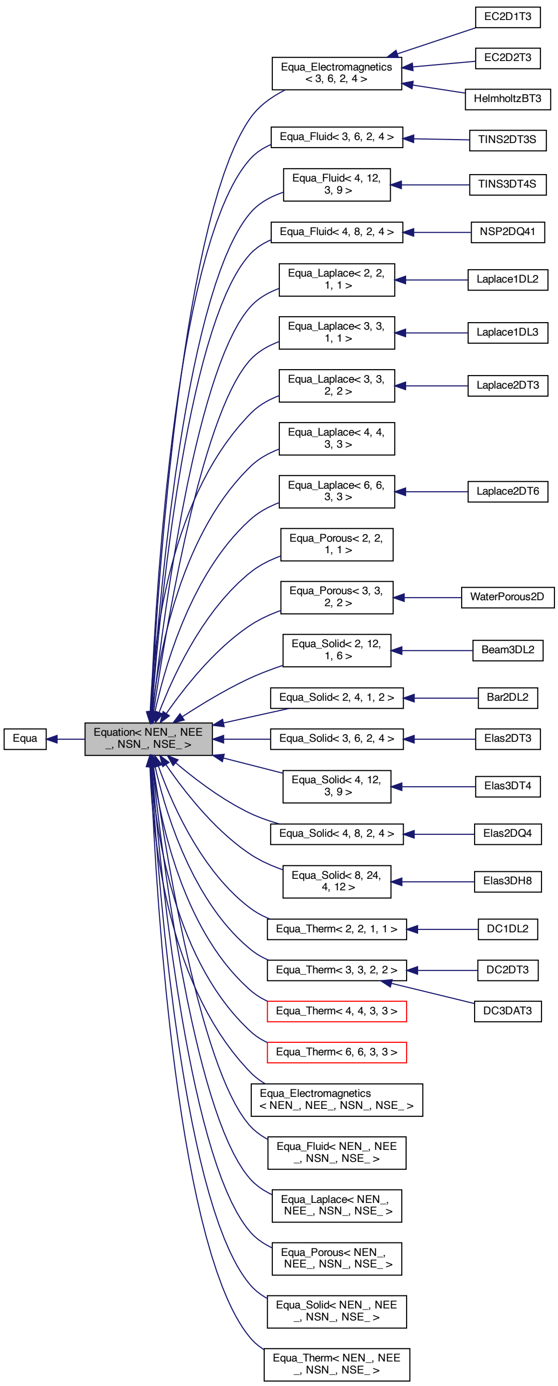
Parameters

in	*e*	Reference to used EigenProblemSolver instance

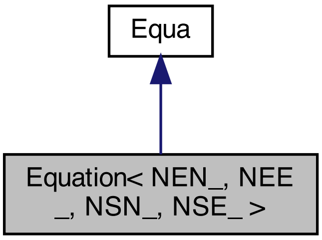
7.35 Equation< NEN_, NEE_, NSN_, NSE_ > Class Template Reference

Abstract class for all equation classes.

Inheritance diagram for Equation< NEN_, NEE_, NSN_, NSE_ >:



Collaboration diagram for Equation< NEN_, NEE_, NSN_, NSE_ >:



Public Member Functions

- Equation ()
- Equation (Mesh &mesh)

  Constructor with mesh instance.
- Equation (Mesh &mesh, Vect< real_t > &u)

  Constructor with mesh instance and solution vector.
- Equation (Mesh &mesh, Vect< real_t > &u, real_t &init_time, real_t &final_time, real_t &time_step)

  Constructor with mesh instance, matrix and right-hand side.
- ~Equation ()

  Destructor.
- void updateBC (const Element &el, const Vect< real_t > &bc)

  Update Right-Hand side by taking into account essential boundary conditions.
- void DiagBC (DOFSupport 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 SideNodeVector (const Vect< real_t > &b, LocalVect< real_t, NSE_ > &bs)

  Localize Side Vector from a Vect instance.
- void SideSideVector (const Vect< real_t > &b, real_t *bs)

  Localize Side 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 ElementNodeVector (const Vect< real_t > &b, LocalVect< real_t, NEN_ > &be, int dof)

  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, DOFSupport dof_type=NODE_DOF, int flag=0)
  Localize Element Vector.
- void SideVector (const Vect< real_t > &b, real_t *sb)
  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 (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 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 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 ElementAssembly (Vect< real_t > &v)
  Assemble element vector into global one.
- void SideAssembly (Vect< real_t > &v)
  Assemble side (edge or face) vector into global one.
- 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.
- real_t setMaterialProperty (const string &exp, const string &prop)

  Define a material property by an algebraic expression.

7.35.1 Detailed Description

template<size_t NEN_, size_t NEE_, size_t NSN_, size_t NSE_>class OFELI::Equation< NEN_, NEE_, NSN_, NSE_ >

Abstract class for all equation classes.
Template Arguments:

- **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	*mesh*	Mesh instance

Equation (Mesh & *mesh*, Vect< real_t > & *u*)

Constructor with mesh instance and solution vector.
Parameters

in	*mesh*	Mesh instance

in	*u*	Vect instance containing solution.

Equation (Mesh & *mesh*, Vect< real_t > & *u*, real_t & *init_time*, real_t & *final_time*, real_t & *time_step*)

Constructor with mesh instance, matrix and right-hand side.

Parameters

in	*mesh*	Mesh instance
in	*u*	Vect instance containing Right-hand side.
in	*init_time*	Initial Time value
in	*final_time*	Final Time value
in	*time_step*	Time step value

7.35.3 Member Function Documentation

void updateBC (const Element & *el*, const Vect< real_t > & *bc*)

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 DiagBC (DOFSupport *dof_type* = `NODE_DOF`, int *dof* = `0`)

Update element matrix to impose bc by diagonalization technique.

Parameters

in	*dof_type*	DOF type option. To choose among the enumerated values: • `NODE_DOF`, DOFs are supported by nodes [Default] • `ELEMENT_DOF`, DOFs are supported by elements • `SIDE_DOF`, DOFs are supported by sides
in	*dof*	DOF setting: • `= 0`, All DOFs are taken into account [Default] • `!= 0`, Only DOF No. `dof` is handled in the system

void LocalNodeVector (Vect< real_t > & *b*)

Localize Element Vector from a Vect instance.

Parameters

in	*b*	Reference to global vector to be localized. The resulting local vector can be accessed by attribute 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*)

Localize Element Vector from a Vect instance.

Parameters

in	*b*	Global vector to be localized.
out	*be*	Local vector, the length of which is the total number of element equations.

Remarks

All degrees of freedom are transferred to the local vector

void SideNodeVector (const Vect< real_t > & *b*, LocalVect< real_t, NSE_ > & *bs*)

Localize Side Vector from a Vect instance.
Parameters

in	*b*	Global vector to be localized.
out	*bs*	Local vector, the length of which is the total number of side equations.

Remarks

All degrees of freedom are transferred to the local vector

void SideSideVector (const Vect< real_t > & *b*, real_t * *bs*)

Localize Side Vector from a Vect instance.
Parameters

in	*b*	Global vector to be localized.
out	*bs*	Local constant value of vector at given side.

Remarks

All degrees of freedom are transferred to the local vector

void ElementNodeVectorSingleDOF (const Vect< real_t > & *b*, LocalVect< real_t, NEN_ > & *be*)

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 `b` is assumed to contain only one degree of freedom by node.

void ElementNodeVector (const Vect< real_t > & *b*, LocalVect< real_t, NEN_ > & *be*, int *dof*)

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 ElementSideVector (const Vect< real_t > & *b*, LocalVect< real_t, NSE_ > & *be*)

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< real_t > & *b*, DOFSupport *dof_type* = `NODE_DOF`, int *flag* = `0`)

Localize Element Vector.
Parameters

in	*b*	Global vector to be localized
in	*dof_type*	DOF type option. To choose among the enumerated values: • `NODE_DOF`, DOFs are supported by nodes [Default] • `ELEMENT_DOF`, DOFs are supported by elements • `SIDE_DOF`, DOFs are supported by sides
in	*flag*	Option to set: • `= 0`, All DOFs are taken into account [Default] • `!= 0`, Only DOF number `dof` is handled in the system 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*, real_t * *sb*)

Localize Side Vector.
Parameters

in	b	Global vector to be localized • NODE_DOF, DOFs are supported by nodes [default] • ELEMENT_DOF, DOFs are supported by elements • SIDE_DOF, DOFs are supported by sides • BOUNDARY_SIDE_DOF, DOFs are supported by boundary sides
out	sb	Array in which local vector is stored 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< real_t > * A)

Assemble element matrix into global one.
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 ElementAssembly (BMatrix< real_t > & A)

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*)

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*)

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*)

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*)

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 DGElementAssembly (Matrix< real_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 SkSMatrix, SkMatrix, SpMatrix)

Warning

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

void DGElementAssembly (SkSMatrix< real_t > & *A*)

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*)

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*)

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*)

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 SideAssembly (Matrix< real_t > * *A*)

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*)

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*)

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*)

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 ElementAssembly (Vect< real_t > & *v*)

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 (Vect< real_t > & *v*)

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 AxbAssembly (const Element & *el*, const Vect< real_t > & *x*, Vect< real_t > & *b*)

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*)

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*)

Define a material property by an algebraic expression.
Parameters

`in`	*exp*	Algebraic expression
`in`	*prop*	Property name

Returns

Return value in expression evaluation:

- `=0`, Normal evaluation
- `!=0`, An error message is displayed

7.36 Estimator Class Reference

To calculate an a posteriori estimator of the solution.

Public Types

- enum EstimatorType {
  ESTIM_ZZ = 0,
  ESTIM_ND_JUMP = 1 }

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.
- void getNodeWiseIndex (Vect< real_t > &e)

  Get vector containing nodewise error index.
- void getSideWiseIndex (Vect< real_t > &e)

  Get vector containing sidewise 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-Zienckiewicz 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	m	Mesh 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: • `ESTIM_ZZ`: The Zhu-Zienckiewicz estimator (Default value) • `ESTIM_ND_JUMP`: An estimator based on the jump of normal derivatives of the solution across mesh sides

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

void getNodeWiseIndex (Vect< real_t > & *e*)

Get vector containing nodewise error index.

Parameters

in,out	e	Vector that contains once the member function setError is invoked a posteriori estimator at each node

void getSideWiseIndex (Vect< real_t > & *e*)

Get vector containing sidewise error index.

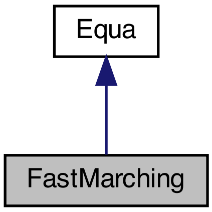
Parameters

in,out	e	Vector that contains once the member function setError is invoked a posteriori estimator at each side

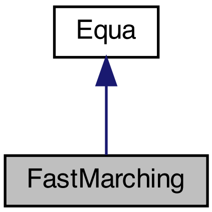
7.37 FastMarching Class Reference

class for the fast marching algorithm on uniform grids

Inheritance diagram for FastMarching:



Collaboration diagram for FastMarching:



Public Member Functions

- FastMarching ()

  Default Constructor.
- FastMarching (const Grid &g, Vect< real_t > &T)

  Constructor using grid data.
- FastMarching (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Constructor.
- ~FastMarching ()

  Destructor.
- void set (const Grid &g, Vect< real_t > &T)

  Define grid and solution vector.
- void set (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Define grid, solution vector and prppagation speed.
- int run ()

Execute Fast Marching Procedure.

- real_t getResidual ()

  Check consistency by computing the discrete residual.

7.37.1 Detailed Description

class for the fast marching algorithm on uniform grids

This class implements the Fast Marching method to solve the eikonal equation in a uniform grid (1-D, 2-D or 3-D). In other words, the class solves the partial differential equation $|\nabla u|F = 1$ with $u = 0$ on the interface, where `F` is the velocity

7.37.2 Constructor & Destructor Documentation

FastMarching ( )

Default Constructor.

Initializes to default value grid data

FastMarching (const Grid & *g*, Vect< real_t > & *T*)

Constructor using grid data.

Constructor using Grid instance

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

FastMarching (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Constructor.

Constructor using Grid instance and propagation speed

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain
in	*F*	Vector containing propagation speed at grid nodes

7.37.3 Member Function Documentation

void set (const Grid & *g*, Vect< real_t > & *T*)

Define grid and solution vector.

This function is to be used if the default constructor has been used

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

void set (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Define grid, solution vector and prppagation speed.

This function is to be used if the default constructor has been used

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain
in	*F*	Vector containing propagation speed at grid nodes

int run ( )

Execute Fast Marching Procedure.

Once this function is invoked, the vector `T` in the constructor or in the member function `set` contains the solution.

Returns

Return value:

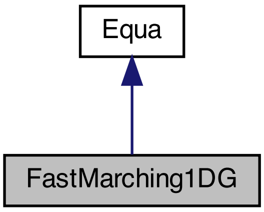
- = 0 if solution has been normally computed
- != 0 An error has occurred

real_t getResidual ( )

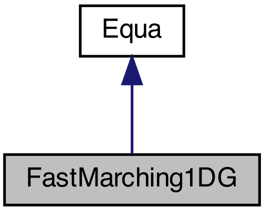
Check consistency by computing the discrete residual.
This function returns residual error (||∇ u|^2|F|-1|)

7.38 FastMarching1DG Class Reference

class for the fast marching algorithm on 1-D uniform grids
Inheritance diagram for FastMarching1DG:



Collaboration diagram for FastMarching1DG:



Public Member Functions

- FastMarching1DG ()

  Default Constructor.
- FastMarching1DG (const Grid &g, Vect< real_t > &T)

  Constructor using grid data.
- FastMarching1DG (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Constructor.
- ~FastMarching1DG ()

  Destructor.

- void set (const Grid &g, Vect< real_t > &T)

  Define grid and solution vector.
- void set (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Define grid, solution vector and prppagation speed.
- int run ()

  Execute Fast Marching Procedure.
- real_t getResidual ()

  Check consistency by computing the discrete residual.

7.38.1 Detailed Description

class for the fast marching algorithm on 1-D uniform grids

This class implements the Fast Marching method to solve the eikonal equation in a 1-D uniform grid. In other words, the class solves the partial differential equation |T'|F = 1 with T = 0 on the interface, where `F` is the velocity

7.38.2 Constructor & Destructor Documentation

FastMarching1DG ( )

Default Constructor.

Initializes to default value grid data

FastMarching1DG (const Grid & *g*, Vect< real_t > & *T*)

Constructor using grid data.

Constructor using Grid instance

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

FastMarching1DG (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Constructor.

Constructor using Grid instance and propagation speed

Parameters

in	*g*	Instance of class Grid

in	T	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain
in	F	Vector containing propagation speed at grid nodes

7.38.3 Member Function Documentation

void set (const Grid & *g*, Vect< real_t > & *T*)

Define grid and solution vector.

This function is to be used if the default constructor has been used

Parameters

in	g	Instance of class Grid
in	T	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

void set (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Define grid, solution vector and prppagation speed.

This function is to be used if the default constructor has been used

Parameters

in	g	Instance of class Grid
in	T	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

in	*F*	Vector containing propagation speed at grid nodes

int run ( )

Execute Fast Marching Procedure.

Once this function is invoked, the vector `phi` in the constructor or in the member function `set` contains the solution.

Returns

Return value:

- = 0 if solution has been normally computed
- != 0 An error has occurred

real_t getResidual ( )

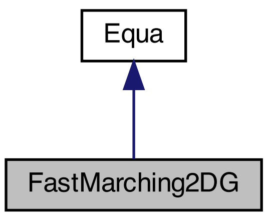
Check consistency by computing the discrete residual.

This function returns residual error (||T'F|-1|)

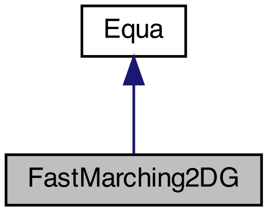
7.39 FastMarching2DG Class Reference

class for the fast marching algorithm on 2-D uniform grids

Inheritance diagram for FastMarching2DG:



Collaboration diagram for FastMarching2DG:



Public Member Functions

- FastMarching2DG ()

  Default Constructor.
- FastMarching2DG (const Grid &g, Vect< real_t > &T)

  Constructor using grid data.
- FastMarching2DG (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Constructor.
- ∼FastMarching2DG ()

  Destructor.
- void set (const Grid &g, Vect< real_t > &T)

  Define grid and solution vector.
- void set (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Define grid, solution vector and prppagation speed.
- int run ()

  Execute Fast Marching Procedure.
- real_t getResidual ()

  Check consistency by computing the discrete residual.

7.39.1 Detailed Description

class for the fast marching algorithm on 2-D uniform grids

This class implements the Fast Marching method to solve the eikonal equation in a 2-D uniform grid. In other words, the class solves the partial differential equation $|\nabla T|F = 1$ with $T = 0$ on the interface, where `F` is the velocity

7.39.2 Constructor & Destructor Documentation

FastMarching2DG ( )

Default Constructor.

Initializes to default value grid data

FastMarching2DG (const Grid & *g*, Vect< real_t > & *T*)

Constructor using grid data.

Constructor using Grid instance

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

FastMarching2DG (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Constructor.

Constructor using Grid instance and propagation speed

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain
in	*F*	Vector containing propagation speed at grid nodes

7.39.3 Member Function Documentation

void set (const Grid & *g*, Vect< real_t > & *T*)

Define grid and solution vector.

This function is to be used if the default constructor has been used

Parameters

in	*g*	Instance of class Grid
in	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

void set (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Define grid, solution vector and prppagation speed.

This function is to be used if the default constructor has been used

Parameters

<table>
<tr><td>in</td><td>g</td><td>Instance of class Grid</td></tr>
<tr><td>in</td><td>T</td><td>Vector containing the on input an initialization of the distance function and once the function <code>run</code> is invoked the distance at grid nodes. The initialization vector must use the following rules:
The solution must be supplied at all grid points in the vicinity of the interface(s).
All other grid nodes must have the value <code>INFINITY</code> wth positive value if the node is in an outer domain and negative if it is in an inner domain</td></tr>
<tr><td>in</td><td>F</td><td>Vector containing propagation speed at grid nodes</td></tr>
</table>

int run ( )

Execute Fast Marching Procedure.

Once this function is invoked, the vector `phi` in the constructor or in the member function `set` contains the solution.

Returns

Return value:

- = 0 if solution has been normally computed
- != 0 An error has occurred

real_t getResidual ( )

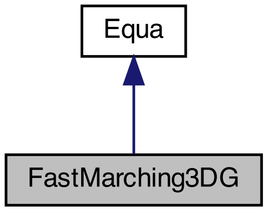
Check consistency by computing the discrete residual.

This function returns residual error ($||\nabla u|^2|F|^2$-1|)

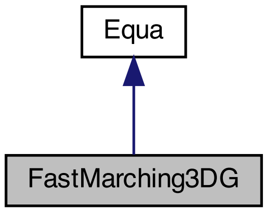
7.40 FastMarching3DG Class Reference

class for the fast marching algorithm on 3-D uniform grids

Inheritance diagram for FastMarching3DG:



Collaboration diagram for FastMarching3DG:



Public Member Functions

- FastMarching3DG ()

  Default Constructor.
- FastMarching3DG (const Grid &g, Vect< real_t > &T)

  Constructor using grid data.
- FastMarching3DG (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Constructor.
- ∼FastMarching3DG ()

  Destructor.
- void set (const Grid &g, Vect< real_t > &T)

  Define grid and solution vector.
- void set (const Grid &g, Vect< real_t > &T, Vect< real_t > &F)

  Define grid, solution vector and prppagation speed.
- int run ()

  Execute Fast Marching Procedure.
- real_t getResidual ()

  Check consistency by computing the discrete residual.

7.40.1 Detailed Description

class for the fast marching algorithm on 3-D uniform grids

This class implements the Fast Marching method to solve the eikonal equation in a 3-D uniform grid. In other words, the class solves the partial differential equation $|\nabla T| F = 1$ with $T = 0$ on the interface, where `F` is the velocity

7.40.2 Constructor & Destructor Documentation

FastMarching3DG ( )

Default Constructor.

Initializes to default value grid data

FastMarching3DG (const Grid & *g*, Vect< real_t > & *T*)

Constructor using grid data.

Constructor using Grid instance

Parameters

`in`	*g*	Instance of class Grid
`in`	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

FastMarching3DG (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Constructor.

Constructor using Grid instance and propagation speed

Parameters

`in`	*g*	Instance of class Grid
`in`	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

`in`	*F*	Vector containing propagation speed at grid nodes

7.40.3 Member Function Documentation

void set (const Grid & *g*, Vect< real_t > & *T*)

Define grid and solution vector.

This function is to be used if the default constructor has been used

Parameters

`in`	*g*	Instance of class Grid
`in`	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

void set (const Grid & *g*, Vect< real_t > & *T*, Vect< real_t > & *F*)

Define grid, solution vector and prppagation speed.

This function is to be used if the default constructor has been used

Parameters

`in`	*g*	Instance of class Grid
`in`	*T*	Vector containing the on input an initialization of the distance function and once the function `run` is invoked the distance at grid nodes. The initialization vector must use the following rules: • The solution must be supplied at all grid points in the vicinity of the interface(s). • All other grid nodes must have the value `INFINITY` wth positive value if the node is in an outer domain and negative if it is in an inner domain

in	*F*	Vector containing propagation speed at grid nodes

int run ( )

Execute Fast Marching Procedure.

Once this function is invoked, the vector `T` in the constructor or in the member function `set` contains the solution

Returns

Return value:

- = 0 if solution has been normally computed
- != 0 An error has occurred

real_t getResidual ( )

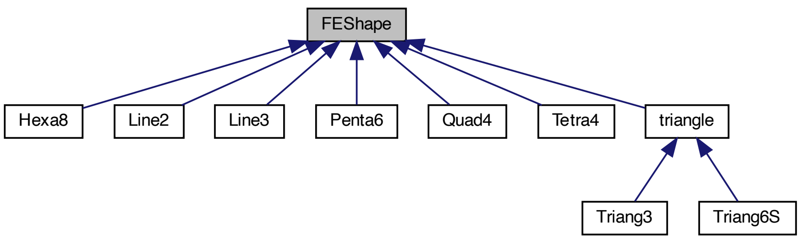
Check consistency by computing the discrete residual.

This function returns residual error ($||\nabla u|^2|F|^2$-1|)

7.41 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`*.*
- 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.

7.41.1 Detailed Description

Parent class from which inherit all finite element shape classes.

Author

Rachid Touzani

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7.41.2 Constructor & Destructor Documentation

FESHape (const Element * *el*)

Constructor for an element.
Parameters

`in`	*el*	Pointer to element

FEShape (const Side * *sd*)

Constructor for a side.
Parameters

`in`	*sd*	Pointer to side

7.41.3 Member Function Documentation

real_t Sh (size_t *i*, Point< real_t > *s*) const

Calculate shape function of node `i` at a given point `s`.
Parameters

`in`	*i*	Local node label
`in`	*s*	Point in the reference triangle where the shape function is evaluated

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 calcuate 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 calcuate relevant quantities.

Point<real_t> getLocalPoint (const Point< real_t > & *s*) const

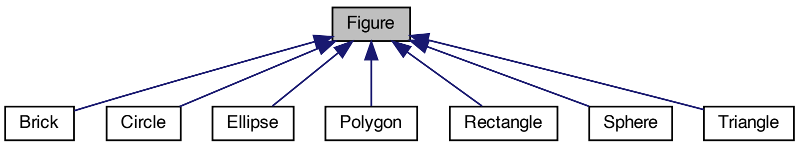
Localize a point in the element.

Return actual coordinates where s are coordinates in the reference element.

7.42 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.

7.42.1 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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7.42.2 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	*p*	Point 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	*g*	Grid instance
in	*d*	Vect instance containing calculated distance from each grid index to Figure

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	*p*	Point for which distance is computed
in	*a*	First vertex of line
in	*b*	Second vertex of line

Returns

Signed distance

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

Funct (string *v1*, string *v2*, string *v3*)

Constructor for a function of three variables.
Parameters

in	*v1*	Name of the first variable
in	*v2*	Name of the second variable
in	*v3*	Name of the third variable

Funct (string *v1*, string *v2*, string *v3*, string *v4*)

Constructor for a function of four variables.
Parameters

in	*v1*	Name of the first variable
in	*v2*	Name of the second variable
in	*v3*	Name of the third variable
in	*v4*	Name of the fourth variable

7.43.3 Member Function Documentation

void operator= (string *e*)

Operator =.
Define the function by an algebraic expression
Parameters

in	*e*	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	*np*	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	*w*	Array of weights of integration points
out	*x*	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 npx)

  Construct a 1-D structured grid given its extremal coordinates and number of intervals.

- Grid (real_t xm, real_t xM, real_t ym, real_t yM, size_t npx, size_t npy)

  Construct a 2-D structured grid given its extremal coordinates and number of intervals.
- Grid (Point< real_t > m, Point< real_t > M, size_t npx, size_t npy)

  Construct a 2-D structured grid given its extremal coordinates and number of intervals.
- Grid (real_t xm, real_t xM, real_t ym, real_t yM, real_t zm, real_t zM, size_t npx, size_t npy, size_t npz)

  Construct a 3-D structured grid given its extremal coordinates and number of intervals.
- Grid (Point< real_t > m, Point< real_t > M, size_t npx, size_t npy, size_t npz)

  Construct a 3-D structured grid given its extremal coordinates and number of intervals.
- void setXMin (const Point< real_t > &x)

  Set min. coordinates of the domain.
- void setXMax (const Point< real_t > &x)
- void setDomain (real_t xmin, real_t xmax)

  Set Dimensions of the domain: 1-D case.
- void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax)

  Set Dimensions of the domain: 2-D case.
- void setDomain (real_t xmin, real_t xmax, real_t ymin, real_t ymax, real_t zmin, real_t zmax)

  Set Dimensions of the domain: 3-D case.
- void setDomain (Point< real_t > xmin, Point< real_t > xmax)

  Set Dimensions of the domain: 3-D case.
- const Point< real_t > & getXMin () const

  Return min. Coordinates of the domain.
- const Point< real_t > & getXMax () const

  Return max. Coordinates of the domain.
- void setN (size_t nx, size_t ny=0, size_t nz=0)

  Set number of grid intervals in the x, y and z-directions.
- void setNbDOF (size_t n)

  Set number of degrees of freedom for a node [Default: `1`].
- 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.
- size_t getNbNodes () const

Return total number of grid nodes.

- size_t getNbDOF () const

  Return total number of dof.

- 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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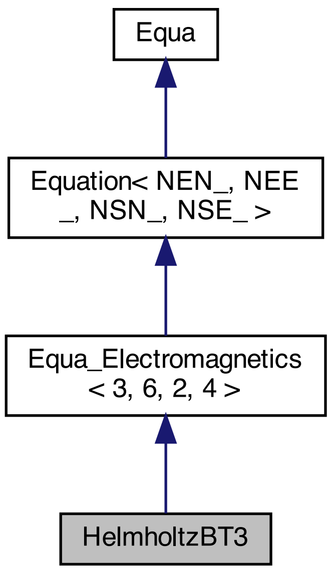
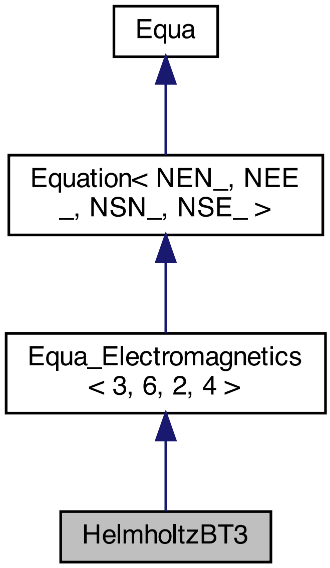
7.46 HelmholtzBT3 Class Reference

Builds finite element arrays for Helmholtz equations in a bounded media using 3-Node triangles.

Inheritance diagram for HelmholtzBT3:



Collaboration diagram for HelmholtzBT3:



Public Member Functions

- HelmholtzBT3 ()

  Default Constructor.
- HelmholtzBT3 (Mesh &ms)

  Constructor using mesh data.
- HelmholtzBT3 (Mesh &ms, Vect< real_t > &u)

  Constructor using mesh and solution vector.
- ∼HelmholtzBT3 ()

  Destructor.
- void build ()

  Builds system of equations.
- void LHS ()

  Add element Left-Hand Side.
- void BodyRHS (Vect< real_t > &f)

  Add element Right-Hand Side.
- void BoundaryRHS (Vect< real_t > &f)

  Add side Right-Hand Side.

Additional Inherited Members

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 but stored in 2-degree of freedom real-valued vector. Therefore, mesh must be defined with 2 degrees of freedom per node

Author

Rachid Touzani

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7.46.2 Constructor & Destructor Documentation

HelmholtzBT3 (Mesh & *ms*)

Constructor using mesh data.

Parameters

in	*ms*	Mesh instance

HelmholtzBT3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and solution vector.

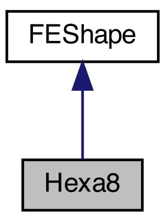
Parameters

in	*ms*	Mesh instance
in,out	*u*	Vect instance containing solution

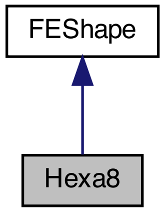
7.47 Hexa8 Class Reference

Defines a three-dimensional 8-node hexahedral finite element using Q1-isoparametric interpolation.

Inheritance diagram for Hexa8:



Collaboration 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.
- void atGauss (int n, std::vector< Point< real_t > > &dsh, std::vector< real_t > &w)

  Calculate shape function derivatives and integration weights.
- void atGauss (int n, std::vector< real_t > &sh, std::vector< real_t > &w)

  Calculate shape functions and integration weights.
- real_t getMaxEdgeLength () const

  Return maximal edge length.
- real_t getMinEdgeLength () const

  Return minimal edge length.
- Point< real_t > Grad (const LocalVect< real_t, 8 > &u, const Point< real_t > &s)

  Return gradient of a function defined at element nodes.

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]x[-1,1]x[-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.

void atGauss (int *n*, std::vector< Point< real_t > > & *dsh*, std::vector< real_t > & *w*)

Calculate shape function derivatives and integration weights.

Parameters

in	*n*	Number of Gauss-Legendre integration points in each direction
in	*dsh*	Vector of shape function derivatives at the Gauss points
in	*w*	Weights of integration formula at Gauss points

void atGauss (int *n*, std::vector< real_t > & *sh*, std::vector< real_t > & *w*)

Calculate shape functions and integration weights.

Parameters

in	*n*	Number of Gauss-Legendre integration points in each direction
in	*sh*	Vector of shape functions at the Gauss points
in	*w*	Weights of integration formula at Gauss points

Point<real_t> Grad (const LocalVect< real_t, 8 > & *u*, const Point< real_t > & *s*)

Return gradient of a function defined at element nodes.

Parameters

in	*u*	Vector of values at nodes
in	*s*	Local coordinates (in `[-1,1]*[-1,1]*[-1,1]`) of point where the gradient is evaluated

Returns

Value of gradient

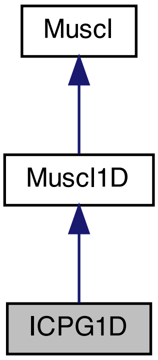
Note

If the derivatives of shape functions were not computed before calling this function (by calling setLocal), this function will compute them

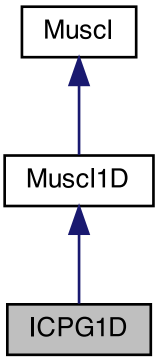
7.48 ICPG1D Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 1-D.

Inheritance diagram for ICPG1D:



Collaboration diagram for ICPG1D:



Public Member Functions

- ICPG1D (Mesh &ms)

  Constructor using Mesh instance.
- ICPG1D (Mesh &ms, Vect< real_t > &r, Vect< real_t > &v, Vect< real_t > &p)

  Constructor using mesh and initial data.
- ~ICPG1D ()

Destructor.

- void setReconstruction ()

    Set reconstruction from class Muscl.

- real_t runOneTimeStep ()

    Advance one time step.

- void Forward (const Vect< real_t > &flux, Vect< real_t > &field)

    Add flux to field.

- void setSolver (SolverType solver)

    Choose solver type.

- void setGamma (real_t gamma)

    Set value of constant Gamma for gases.

- void setCv (real_t Cv)

    Set value of Cv (specific heat at constant volume)

- void setCp (real_t Cp)

    Set value of 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.

Additional Inherited Members

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 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	*ms*	Reference to Mesh instance
in	*r*	Vector containing initial (elementwise) density
in	*v*	Vector containing initial (elementwise) velocity
in	*p*	Vector containing initial (elementwise) pressure

7.48.3 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	*flux*	Vector containing fluxes at sides (points)
out	*field*	Vector containing solution vector

void getMomentum (Vect< real_t > & *m*) const

Get vector of momentum at elements.

Parameters

in,out	*m*	Vect instance that contains on output element momentum

void getInternalEnergy (Vect< real_t > & *ie*) const

Get vector of internal energy at elements.
Parameters

in,out	*ie*	Vect 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	*te*	Vect 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	*s*	Vect instance that contains on output element sound speed

void getMach (Vect< real_t > & *m*) const

Get vector of elementwise Mach number.
Parameters

in,out	*m*	Vect instance that contains on output element Mach number

void setInitialCondition (const LocalVect< real_t, 3 > & *u*)

A constant initial condition.
Parameters

in	*u*	LocalVect 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	*sd*	Side to which the value is assigned
in	*u*	Value to assign

void setBC (int *code*, real_t *a*)

Assign a boundary condition value.

Parameters

in	*code*	Code value to which boundary condition is assigned
in	*a*	Value to assign to sides that have code `code`

void setBC (real_t *a*)

Assign a boundary condition value.

Parameters

in	*a*	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	*sd*	Side instance to which the values are assigned
in	*u*	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	*code*	Side code for which the values are assigned
in	*U*	LocalVect instance that contains values to assign to sides with code *code*

void setBC (const LocalVect< real_t, 3 > & *u*)

Assign a Dirichlet boundary condition vector.

Parameters

in	*u*	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	*sd*	Instance of Side on which the condition is prescribed
in	*u*	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	*code*	Value of code for which the condition is prescribed
in	*u*	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.

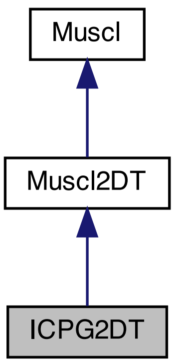
Parameters

in	*u*	LocalVect instance that contains values to assign to the sides

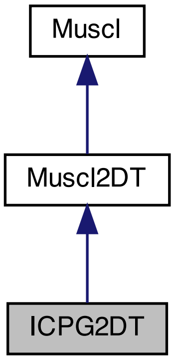
7.49 ICPG2DT Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 2-D.

Inheritance diagram for ICPG2DT:



Collaboration diagram for ICPG2DT:



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 setInitialConditionShockTube (const LocalVect< real_t, 4 > &BcL, const LocalVect< real_t, 4 > &BcR, real_t x0)

  Set initial condition for the schock tube problem.
- void setInitialCondition (const LocalVect< real_t, 4 > &u)

  Set initial condition.
- 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.

Additional Inherited Members

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 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	*ms*	Mesh instance
in	*r*	Initial density vector (as instance of Vect)
in	*v*	Initial velocity vector (as instance of Vect)
in	*p*	Initial pressure vector (as instance of Vect)

7.49.3 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	*s*	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	*sd*	Reference to Side instance
in	*a*	Value to prescribe

void setBC (int *code*, real_t *a*)

Prescribe a constant boundary condition for a given code.
Parameters

in	*code*	Code for which value is imposed
in	*a*	Value to prescribe

void setBC (real_t *u*)

Prescribe a constant boundary condition on all boundary sides.
Parameters

in	*u*	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	*sd*	Reference to Side instance
in	*u*	Vector (instance of class LocalVect) with as components the constant values to prescribe for the four fields (`r`, `vx`, `vy`, `p`)

void setBC (int *code*, const LocalVect< real_t, 4 > & *u*)

Prescribe a constant boundary condition for a given code.
Parameters

in	*code*	Code for which value is imposed
in	*u*	Vector (instance of class LocalVect) with as components the constant values to prescribe for the four fields (`r`, `vx`, `vy`, `p`)

void setBC (const LocalVect< real_t, 4 > & *u*)

Prescribe a constant boundary condition at all boundary sides.
Parameters

in	*u*	Vector (instance of class LocalVect) with as components the constant values to prescribe for the four fields (`r`, `vx`, `vy`, `p`)

real_t getR (size_t *i*) const

Return density at given element label.

Parameters

in	*i*	Element label

real_t getV (size_t *i*, size_t *j*) const

Return velocity at given element label

Parameters

in	*i*	Element label
in	*j*	component index (1 or 2)

real_t getP (size_t *i*) const

Return pressure at given element label.

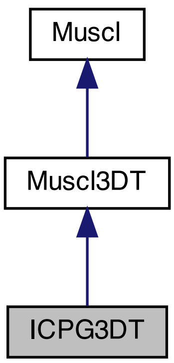
Parameters

in	*i*	Element label

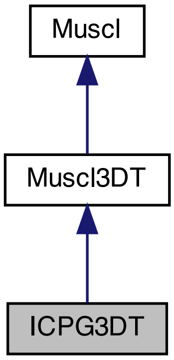
7.50 ICPG3DT Class Reference

Class to solve the Inviscid compressible fluid flows (Euler equations) for perfect gas in 3-D.

Inheritance diagram for ICPG3DT:



Collaboration diagram for ICPG3DT:



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 setSolver (SolverType solver)

  Choose solver.
- 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 γ 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 γ.
- 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 κ.
- 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.
- void setInitialConditionShockTube (const LocalVect< real_t, 5 > &BcG, const LocalVect< real_t, 5 > &BcD, real_t x0)
  Set initial condition for the schock tube problem.
- void setInitialCondition (const LocalVect< real_t, 5 > &u)
  Set initial condition.

Additional Inherited Members

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 Constructor & Destructor Documentation

ICPG3DT (Mesh & *ms*)

Constructor using mesh data.

Parameters

in	*ms*	Mesh instance

ICPG3DT (Mesh & *ms*, Vect< real_t > & *r*, Vect< real_t > & *v*, Vect< real_t > & *p*)

Constructor using mesh and initial data.
Parameters

in	*ms*	Mesh instance
in	*r*	Elementwise initial density vector (as instance of Element Vect)
in	*v*	Elementwise initial velocity vector (as instance of Element Vect)
in	*p*	Elementwise initial pressure vector (as instance of Element Vect)

7.50.3 Member Function Documentation

void setReconstruction ( )

Reconstruct.
exit(3) if reconstruction failed

7.51 Integration Class Reference

Class for numerical integration methods.

Public Member Functions

- Integration ()

  Default constructor.
- Integration (real_t low, real_t high, function< real_t(real_t)> const &f, IntegrationScheme s, real_t error)

  Constructor.
- ∼Integration ()

  Destructor.
- void setFunction (function< real_t(real_t)> const &f)

  Define function to integrate numerically.
- void setScheme (IntegrationScheme s)

  Set time ingration scheme.
- void setTriangle (real_t x1, real_t y1, real_t x2, real_t y2, real_t x3, real_t y3)

  Define integration domain as a quadrilateral.
- void setQuadrilateral (real_t x1, real_t y1, real_t x2, real_t y2, real_t x3, real_t y3, real_t x4, real_t y4)

  Define integration domain as a quadrilateral.
- real_t run ()

  Run numerical integration.

7.51.1 Detailed Description

Class for numerical integration methods.

Class NumInt defines and stores numerical integration data

Author

Rachid Touzani

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7.51.2 Constructor & Destructor Documentation

Integration (real_t *low*, **real_t** *high*, **function< real_t(real_t)> const &** *f*, **IntegrationScheme** *s*, **real_t** *error* **)**

Constructor.
Parameters

`in`	*low*	Lower value of integration interval
`in`	*high*	Upper value of integration interval
`in`	*f*	Function to integrate
`in`	*s*	Integration scheme. To choose among enumerated values: • `LEFT_RECTANGLE`: • `RIGHT_RECTANGLE`: • `MID_RECTANGLE`: • `TRAPEZOIDAL`: • `SIMPSON`: • `GAUSS_LEGENDRE`:
`in`	*error*	

7.51.3 Member Function Documentation

void setFunction (function< real_t(real_t)> const & *f* **)**

Define function to integrate numerically.
Parameters

`in`	*f*	Function to integrate

void setScheme (IntegrationScheme *s* **)**

Set time ingration scheme.
Parameters

in	*s*	Scheme to choose among enumerated values: • `LEFT_RECTANGLE`: • `RIGHT_RECTANGLE`: • `MID_RECTANGLE`: • `TRAPEZOIDAL`: • `SIMPSON`: • `GAUSS_LEGENDRE`:

void setTriangle (real_t *x1*, real_t *y1*, real_t *x2*, real_t *y2*, real_t *x3*, real_t *y3*)

Define integration domain as a quadrilateral.
Parameters

in	*x1*	x-coordinate of first vertex of triangle
in	*y1*	y-coordinate of first vertex of triangle
in	*x2*	x-coordinate of second vertex of triangle
in	*y2*	y-coordinate of second vertex of triangle
in	*x3*	x-coordinate of third vertex of triangle
in	*y3*	y-coordinate of third vertex of triangle

void setQuadrilateral (real_t *x1*, real_t *y1*, real_t *x2*, real_t *y2*, real_t *x3*, real_t *y3*, real_t *x4*, real_t *y4*)

Define integration domain as a quadrilateral.
Parameters

in	*x1*	x-coordinate of first vertex of quadrilateral
in	*y1*	y-coordinate of first vertex of quadrilateral
in	*x2*	x-coordinate of second vertex of quadrilateral
in	*y2*	y-coordinate of second vertex of quadrilateral
in	*x3*	x-coordinate of third vertex of quadrilateral
in	*y3*	y-coordinate of third vertex of quadrilateral
in	*x4*	x-coordinate of fourth vertex of quadrilateral
in	*y4*	y-coordinate of fourth vertex of quadrilateral

real_t run ( )

Run numerical integration.

Returns

Computed approximate value of integral

7.52 IOField Class Reference

Enables working with files in the XML Format.
Inherits XMLParser.

Public Types

- enum AccessType

  Enumerated values for file access type.

Public Member Functions

- IOField ()

  Default constructor.
- IOField (const string &file, AccessType access, bool compact=true)

  Constructor using file name.
- IOField (const string &mesh_file, const string &file, Mesh &ms, AccessType access, bool compact=true)

  Constructor using file name, mesh file and mesh.
- IOField (const string &file, Mesh &ms, AccessType access, bool compact=true)

  Constructor using file name and mesh.
- IOField (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.
- 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.*

7.52.1 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

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7.53 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 ()
  *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 pameter 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.

7.53.1 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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7.53.2 Constructor & Destructor Documentation

IPF (const string & *file*)

Constructor that gives the data file name.

It reads parameters in IPF Format from this file.

7.53.3 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	*label*	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	*label*	Label that identifies the string (read from input file)
in	*def*	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	*label*	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	*label*	Label that identifies the integer number (read from input file).
in	*def*	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	*label*	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	*label*	Label that identifies the real number (read from input file)
in	*def*	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	*label*	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	*label*	Label that identifies the complex number (read from input file)
in	*def*	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	*label*	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	*label*	Label that identifies the array (read from input file).
in	*a*	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	*label*	Label that identifies the array (read from input file).
in	*j*	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	*label*	Label that identifies the integer number (read from input file).
out	*a*	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	*label*	Label that identifies the real (real_t) number (read from input file).
out	*a*	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	*label*	Label that identifies the complex number (read from input file).
out	*a*	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	*label*	Label that identifies the atring (read from input file).
out	*a*	Returned value. Note: This member function can be used instead of getString If this label is not found an error message is displayed and program stops. Note: This member function can be used instead of getString

string getProject ( ) const

Return parameter read using keyword **Project**.
This parameter can be used to read a project's name.

string getMeshFile (size_t *i* = 1) const

Return `i`-th parameter read using keyword **mesh_file**.
Here we have at most 10 integer extra parameters that can be used for any purpose. Default value for `i` is `1`

string getInitFile ( ) const

Return parameter read using keyword **InitFile**.
This parameter can be used to read an initial data file name.

string getRestartFile ( ) const

Return parameter read using keyword **RestartFile**.
This parameter can be used to read a restart file name.

string getBCFile ( ) const

Return parameter read using keyword **BCFile**.
This parameter can be used to read a boundary condition file name.

string getBFFile ( ) const

Return parameter read using keyword **BFFile**.
This parameter can be used to read a body force file name.

string getSFFile ( ) const

Return parameter read using keyword **SFFile**.
This parameter can be used to read a source force file name.

string getSaveFile ( ) const

Return parameter read using keyword **SaveFile**.
This parameter can be used to read a save file name.

string getPlotFile (int *i* = 1) const

Return `i`-th parameter read using keyword **PlotFile**.
Here we have at most 10 integer extra parameters that can be used for plot file names. Default value for `i` is `1`

string getPrescriptionFile (int *i* = *1*) const

Return parameter read using keyword **DataFile**.
This parameter can be used to read a Prescription file.

string getAuxFile (size_t *i* = *1*) const

Return `i`-th parameter read using keyword **Auxfile**.
Here we have at most 10 integer extra parameters that can be used for any auxiliary file names. Default value for `i` is `1`

7.54 Iter< T_ > Class Template Reference

Class to drive an iterative process.

Public Member Functions

- Iter ()

  Default Constructor.
- Iter (int max_it, real_t toler)

  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)

7.54.1 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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7.54.2 Member Function Documentation

void setMaxIter (int *max_it*)

Set maximal number of iterations.

Parameters

in	*max_it*	Maximal number of iterations [Default: `100`]

void setTolerance (real_t *toler*)

Set tolerance value for convergence.

Parameters

in	*toler*	Tolerance value [Default: `1.e-8`]

void setVerbose (int *v*)

Set verbosity parameter.

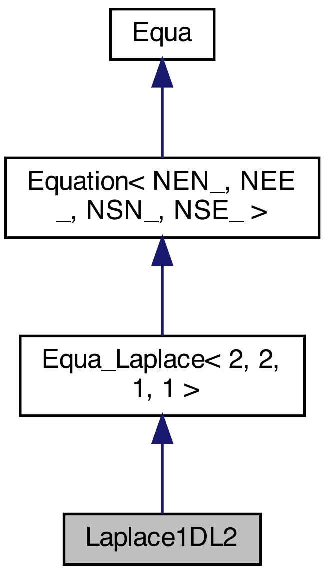
Parameters

in	*v*	Verbosity parameter [Default: `0`]

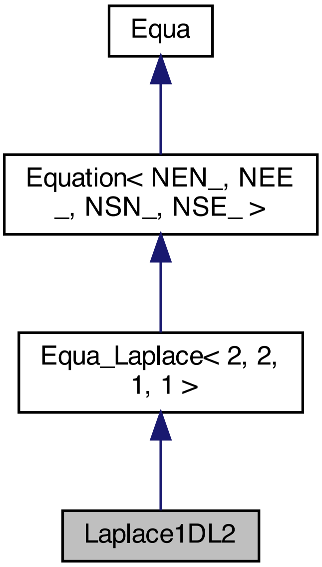
7.55 Laplace1DL2 Class Reference

To build element equation for a 1-D elliptic equation using the 2-Node line element (P_1).

Inheritance diagram for Laplace1DL2:



Collaboration diagram for Laplace1DL2:



Public Member Functions

- Laplace1DL2 ()

  Default constructor.
- Laplace1DL2 (Mesh &ms, Vect< real_t > &u)
- Laplace1DL2 (Mesh &ms)
- ∼Laplace1DL2 ()

  Destructor.
- void LHS ()

  Add finite element matrix to left hand side.
- void buildEigen (int opt=0)

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

7.55.1 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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7.55.2 Constructor & Destructor Documentation

Laplace1DL2 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh instance and solution vector

Parameters

in	*ms*	Mesh instance
in,out	*u*	Vect instance that contains, after execution of **run()** the solution

Laplace1DL2 (Mesh & *ms*)

Constructor using mesh instance

Parameters

in	*ms*	Mesh instance

7.55.3 Member Function Documentation

void buildEigen (int *opt* = *0*) `[virtual]`

Build global stiffness and mass matrices for the eigen system.

Parameters

in	*opt*	Flag to choose a lumped mass matrix (0) or consistent (1) [Default: 0]

Reimplemented from Equa_Laplace< 2, 2, 1, 1 >.

void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

Add Right-Hand Side Contribution.

Parameters

in	*f*	Vector containing the source given function at mesh nodes

Reimplemented from Equa_Laplace< 2, 2, 1, 1 >.

void BoundaryRHS (const Vect< real_t > & *f*) `[virtual]`

Add Neumann contribution to Right-Hand Side.

Parameters

in	*f*	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< 2, 2, 1, 1 >.

void setBoundaryCondition (real_t *f*, int *lr*)

Set Dirichlet boundary data.

Parameters

in	*f*	Value to assign
in	*lr*	Option to choose location of the value (-1: Left end, 1: Right end)

void setTraction (real_t *f*, int *lr*)

Set Traction data.

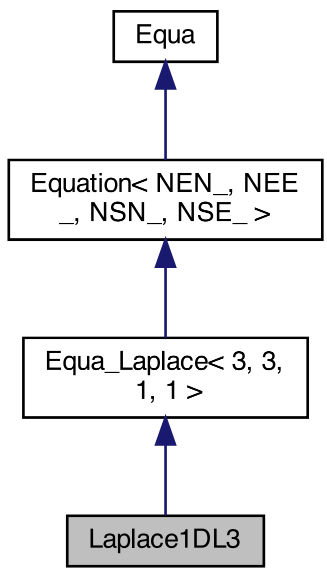
Parameters

in	*f*	Value of traction (Neumann boundary condition)
in	*lr*	Option to choose location of the traction (-1: Left end, 1: Right end)

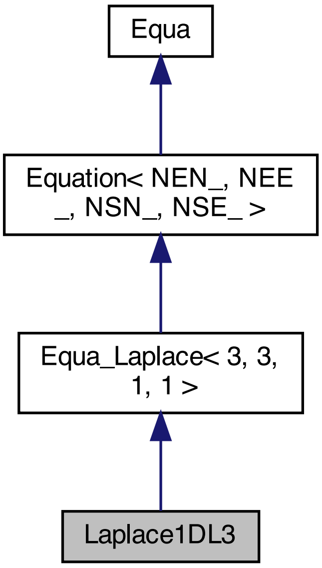
7.56 Laplace1DL3 Class Reference

To build element equation for the 1-D elliptic equation using the 3-Node line (P_2).

Inheritance diagram for Laplace1DL3:



Collaboration diagram for Laplace1DL3:



Public Member Functions

- Laplace1DL3 ()

  Default constructor. Initializes an empty equation.
- Laplace1DL3 (Mesh &ms)

  Constructor using mesh instance.
- Laplace1DL3 (Mesh &ms, Vect< real_t > &u)
- ~Laplace1DL3 ()

  Destructor.
- void LHS ()

  Compute element matrix.
- 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.

7.56.1 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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7.56.2 Constructor & Destructor Documentation

Laplace1DL3 (Mesh & *ms*)

Constructor using mesh instance.

Parameters

in	*ms*	Mesh instance

Laplace1DL3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh instance and solution vector

Parameters

in	*ms*	Mesh instance
in,out	*u*	Vect instance that contains, after execution of **run()** the solution

7.56.3 Member Function Documentation

void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

Add Right-hand side contribution.

Parameters

in	*f*	Vector of right-hand side of the Poisson equation at nodes

Reimplemented from Equa_Laplace< 3, 3, 1, 1 >.

void BoundaryRHS (const Vect< real_t > & *h*) `[virtual]`

Add Neumann contribution to Right-Hand Side.

Parameters

in	*h*	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< 3, 3, 1, 1 >.

void setTraction (real_t *f*, int *lr*)

Set Traction data.

Parameters

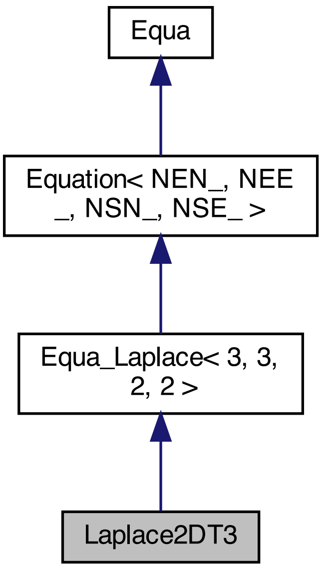
in	*f*	Value of traction (Neumann boundary condition)

in	*lr*	Option to choose location of the traction (-1: Left end, 1: Right end)

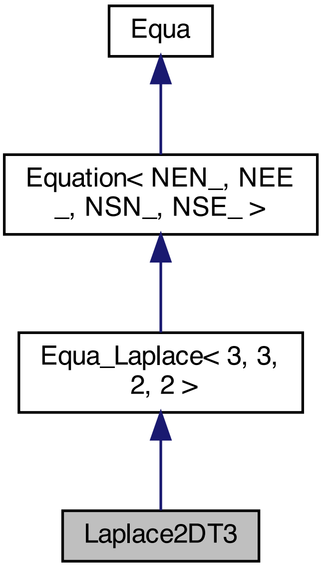
7.57 Laplace2DT3 Class Reference

To build element equation for the Laplace equation using the 2-D triangle element (P_1).

Inheritance diagram for Laplace2DT3:



Collaboration diagram for Laplace2DT3:



Public Member Functions

- Laplace2DT3 ()

  Default constructor.
- Laplace2DT3 (Mesh &ms)

  Constructor with mesh.
- Laplace2DT3 (Mesh &ms, Vect< real_t > &u)

  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 ()

  Destructor.
- void LHS ()

  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.

7.57.1 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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7.57.2 Constructor & Destructor Documentation

Laplace2DT3 (Mesh & *ms*)

Constructor with mesh.

Parameters

in	*ms*	Mesh instance

Laplace2DT3 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and solution vector.

Parameters

in	*ms*	Mesh instance
in	*u*	Problem right-hand side

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.

This constructor sets data for the Poisson equation with mixed (Dirichlet and Neumann) boundary conditions.

Parameters

in	*ms*	Mesh instance
in	*b*	Vector containing the source term (right-hand side of the equation) at mesh nodes
in	*Dbc*	Vector containing prescribed values of the solution (Dirichlet boundary condition) at nodes with positive code. Its size is the total number of nodes
in	*Nbc*	Vector containing prescribed fluxes (Neumann boundary conditions) at sides, its size is the total number of sides
in	*u*	Vector to contain the finite element solution at nodes once the member function run() is called.

7.57.3 Member Function Documentation

void BodyRHS (const Vect< real_t > & *f*) [virtual]

Add body source term to right-hand side.

Parameters

in	*f*	Vector containing the source given function at mesh nodes

Reimplemented from Equa_Laplace< 3, 3, 2, 2 >.

void BoundaryRHS (const Vect< real_t > & *h*) [virtual]

Add boundary source term to right-hand side.

Parameters

in	*h*	Vector containing the source given function at mesh nodes

Reimplemented from Equa_Laplace< 3, 3, 2, 2 >.

void buildEigen (int *opt* = *0*) [virtual]

Build global stiffness and mass matrices for the eigen system.

Parameters

in	*opt*	Flag to choose a lumped mass matrix (0) or consistent (1) [Default: 0]

Reimplemented from Equa_Laplace< 3, 3, 2, 2 >.

void Post (const Vect< real_t > & *u*, Vect< Point< real_t > > & *p*)

Perform post calculations.

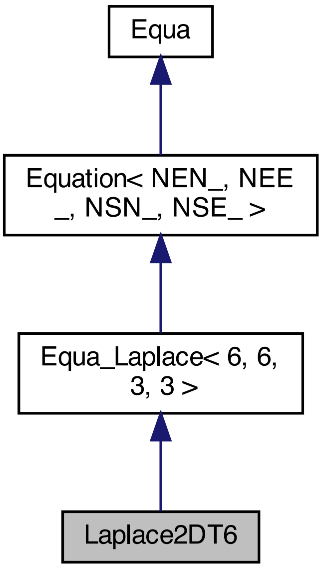
Parameters

in	*u*	Solution at nodes
out	*p*	Vector containing gradient at elements

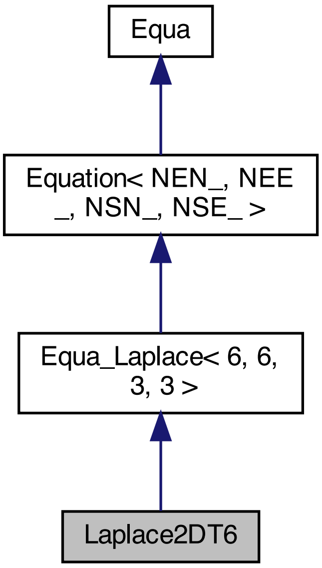
7.58 Laplace2DT6 Class Reference

To build element equation for the Laplace equation using the 2-D triangle element (P_2).

Inheritance diagram for Laplace2DT6:



Collaboration diagram for Laplace2DT6:



Public Member Functions

- Laplace2DT6 ()

  Default constructor.
- Laplace2DT6 (Mesh &ms)

  Constructor with mesh.
- Laplace2DT6 (Mesh &ms, Vect< real_t > &u)

  Constructor using mesh and solution vector.
- ∼Laplace2DT6 ()

  Destructor.
- void LHS ()

  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.

7.58.1 Detailed Description

To build element equation for the Laplace equation using the 2-D triangle element (P_2).

Author

Rachid Touzani

Copyright

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7.58.2 Constructor & Destructor Documentation

Laplace2DT6 (Mesh & *ms*)

Constructor with mesh.
Parameters

in	*ms*	Mesh instance

Laplace2DT6 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and solution vector.
Parameters

in	*ms*	Mesh instance
in	*u*	Problem right-hand side

7.58.3 Member Function Documentation

void BodyRHS (const Vect< real_t > & *f*) `[virtual]`

Add body source term to right-hand side.
Parameters

in	*f*	Vector containing the source given function at mesh nodes

Reimplemented from Equa_Laplace< 6, 6, 3, 3 >.

void BoundaryRHS (const Vect< real_t > & *h*) `[virtual]`

Add boundary source term to right-hand side.
Parameters

in	*h*	Vector containing the source given function at mesh nodes

Reimplemented from Equa_Laplace< 6, 6, 3, 3 >.

void buildEigen (int *opt* = *0*) `[virtual]`

Build global stiffness and mass matrices for the eigen system.
Parameters

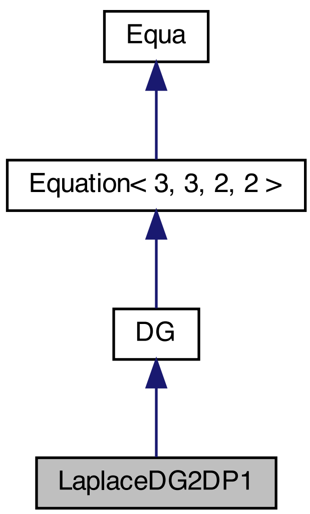
in	*opt*	Flag to choose a lumed mass matrix (0) or consistent (1) [Default: 0]

Reimplemented from Equa_Laplace< 6, 6, 3, 3 >.

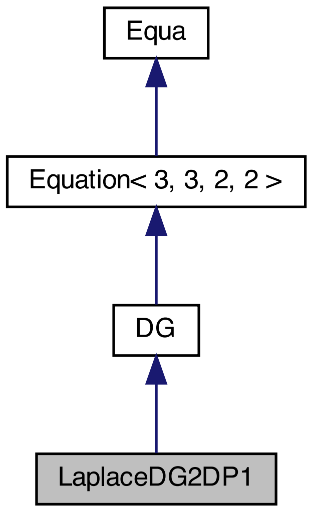
7.59 LaplaceDG2DP1 Class Reference

To build and solve the linear system for the Poisson problem using the DG P_1 2-D triangle element.

Inheritance diagram for LaplaceDG2DP1:



Collaboration 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.

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	*ms*	Mesh instance
in	*f*	Vector containing the right-hand side of the elliptic equation at triangle vertices
in	*Dbc*	Vector containing prescribed values of the solution (Dirichlet boundary condition) at nodes having a positive code
in	*Nbc*	Vector containing prescribed values of the flux (Neumann boundary condition) at each side having a positive code
in	*u*	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	*sigma*	Penalty parameters to enforce continuity at nodes (Must be positive) [Default: `100`]
in	*eps*	Epsilon value of the DG method to choose among the values: • 0 Incomplete Interior Penalty Galerkin method (IIPG) • -1 Symmetric Interior Penalty Galerkin method (SIPG) • 1 Non symmetric interior penalty Galerkin method (NIPG) For a user not familiar with the method, please choose the value of `eps=-1` and `sigma>100` which leads to a symmetric positive definite matrix [Default: `-1`]

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.

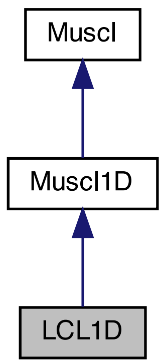
Returns

Number of performed iterations. Note that the maximal number is 1000 and the tolerance is 1.e-8

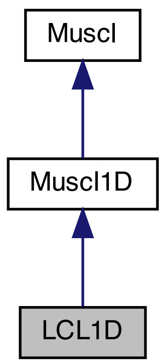
7.60 LCL1D Class Reference

Class to solve the linear conservation law (Hyperbolic equation) in 1-D by a MUSCL Finite Volume scheme.

Inheritance diagram for LCL1D:



Collaboration diagram for LCL1D:



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->n+1.

Additional Inherited Members

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 Function Documentation

void setInitialCondition (Vect< real_t > & *u*)

Assign initial condition by a vector.

Parameters

in	*u*	Vector containing initial condition

void setInitialCondition (real_t *u*)

Assign a constant initial condition.

Parameters

in	*u*	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	*sd*	Side to which value is prescibed
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 prescibed
in	*u*	Value to prescribe

void setVelocity (Vect< real_t > & *v*)

Set convection velocity.

Parameters

in	*v*	Vect instance containing velocity

void Forward (const Vect< real_t > & *Flux*, Vect< real_t > & *Field*)

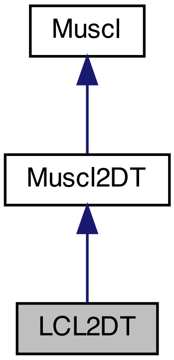
Computation of the primal variable n->n+1.

Vector **Flux** contains elementwise fluxes issued from the Riemann problem, calculated with, as left element, **getNeighborElement(1)** and right element **getNeighborElement(2)** if **getNeighbor←Element(2)** doesn't exist, we are on a boundary and we prescribe a symmetry condition

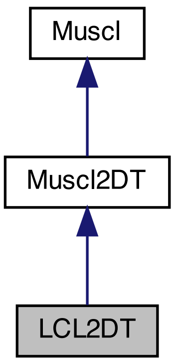
7.61 LCL2DT Class Reference

Class to solve the linear hyperbolic equation in 2-D by a MUSCL Finite Volume scheme on triangles.

Inheritance diagram for LCL2DT:



Collaboration diagram for LCL2DT:



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->n+1.

Additional Inherited Members

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 Constructor & Destructor Documentation

LCL2DT (Mesh & *m*, Vect< real_t > & *U*)

Constructor using mesh and initial data.

Parameters

in	*m*	Reference to Mesh instance
in	*U*	Vector containing initial (elementwise) solution

7.61.3 Member Function Documentation

void setInitialCondition (Vect< real_t > & *u*)

Set elementwise initial condition.
Parameters

in	*u*	Vect 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

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	*sd*	Side to which value is prescibed
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 prescibed

in	u	Value to prescribe

void setVelocity (const Vect< real_t > & *v*)

Set convection velocity.
Parameters

in	v	Vect instance containing velocity

void setVelocity (const LocalVect< real_t, 2 > & *v*)

Set (constant) convection velocity.
Parameters

in	v	Vector containing constant velocity to prescribe

void Forward (const Vect< real_t > & *Flux*, Vect< real_t > & *Field*)

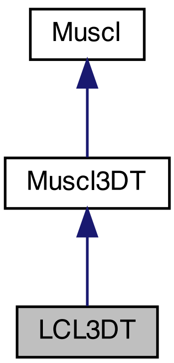
Computation of the primal variable n->n+1.

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

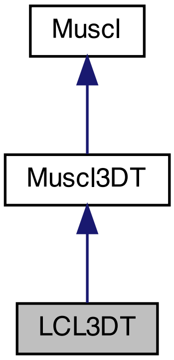
7.62 LCL3DT Class Reference

Class to solve the linear conservation law equation in 3-D by a MUSCL Finite Volume scheme on tetrahedra.

Inheritance diagram for LCL3DT:



Collaboration diagram for LCL3DT:



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->n+1.

Additional Inherited Members

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 Constructor & Destructor Documentation

LCL3DT (Mesh & *m*, Vect< real_t > & *U*)

Constructor using mesh and initial field.

Parameters

in	*m*	Reference to Mesh instance
in	*U*	Vector containing initial (elementwise) solution

7.62.3 Member Function Documentation

void setInitialCondition (Vect< real_t > & *u*)

Set elementwise initial condition.

Parameters

in	*u*	Vect 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*	Side to which value is prescibed
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 prescibed
in	*u*	Value to prescribe

void setVelocity (const Vect< real_t > & *v*)

Set convection velocity.

Parameters

in	*v*	Vect 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*)

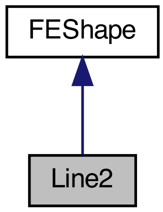
Computation of the primal variable n->n+1.

Vector `Flux` contains elementwise fluxes issued from the Riemann problem, calculated with, as left element, **getNeighborElement(1)** and right element **getNeighborElement(2)** if **getNeighbor↩ Element(2)** doesn't exist, we are on a boundary and we prescribe a symmetry condition

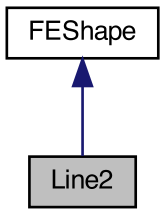
7.63 Line2 Class Reference

To describe a 2-Node planar line finite element.

Inheritance diagram for Line2:



Collaboration 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.
- std::vector< Point< real_t > > DSh () const
  Return partial derivatives of shape functions of element nodes.
- 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.

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	*el*	Pointer to element

Line2 (const Side ∗ *side*)

Constructor for a side.
Parameters

in	*side*	Pointer to side

Line2 (const Edge ∗ *edge*)

Constructor for an edge.
Parameters

in	*edge*	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	Node number (1 or 2).
in	s	Localization of point in natural coordinates (must be between -1 and 1).

std::vector<Point<real_t> > DSh ( ) const

Return partial derivatives of shape functions of element nodes.

Returns

LocalVect instance of partial derivatives of shape functions *e.g.* `dsh(i).x`, `dsh(i).y`, are partial derivatives of the *i*-th shape function.

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.

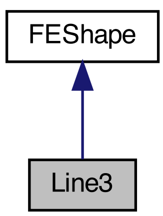
Parameters

in	x	Point where interpolation is evaluated (in the reference element).
out	v	Computed value.

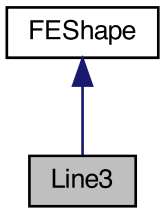
7.64 Line3 Class Reference

To describe a 3-Node quadratic planar line finite element.

Inheritance diagram for Line3:



Collaboration 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.
- LocalVect< Point< real_t >, 3 > DSh () const

  Return partial derivatives of shape functions of element nodes.
- Point< real_t > getLocalPoint () const

  Return actual coordinates of localized point.

7.64.1 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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7.64.2 Member Function Documentation

LocalVect<Point<real_t>,3> DSh ( ) const

Return partial derivatives of shape functions of element nodes.

Returns

LocalVect instance of partial derivatives of shape functions *e.g.* `dsh(i)`.x, `dsh(i)`.y, are partial derivatives of the *i*-th shape function.

Note

The local point at which the derivatives are computed must be chosen before by using the member function setLocal

7.65 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)
  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 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.
- Preconditioner getPreconditioner () const

  Return solver preconditioner.
- 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.
- int getNbIter () const

  Get number of performed iterations.

7.65.1 Detailed Description

template<class T_>class OFELI::LinearSolver< T_ >

Class to solve systems of linear equations by iterative methods.

7.65.2 Constructor & Destructor Documentation

LinearSolver ( )

Default Constructor.
Initializes default parameters and pointers to 0.

LinearSolver (int *max_it*, real_t *tolerance*)

Constructor with iteration parameters.

Parameters

in	*max_it*	Maximal number of iterations
in	*tolerance*	Tolerance for convergence (measured in relative weighted 2-Norm) in input, effective discrepancy in output.

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	*A*	Reference to instance of class SpMatrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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	*A*	SkMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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	*A*	TrMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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*	BMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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*	DMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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*	DSMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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*	SkMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect 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	*A*	SkMatrix instance that contains matrix
in	*b*	Vect instance that contains the right-hand side
in,out	*x*	Vect instance that contains the initial guess on input and solution on output

7.65.3 Member Function Documentation

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	A	Pointer to abstract Matrix class

void setMatrix (SpMatrix< T_ > & A)

Set matrix in the case of a pointer to matrix.
Parameters

in	A	Pointer to abstract Matrix class

void setMatrix (SkMatrix< T_ > & A)

Set matrix in the case of a skyline matrix.
Parameters

in	A	Matrix as instance of class SkMatrix

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 SpMatrix 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 SpMatrix 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	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`, `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.

7.66 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 witrh respect to matrix.
- T_ * get ()

  Return pointer to matrix as a C-array.

7.66.1 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_*	Data type (double, float, complex<double>, ...)
*NR_*	number of rows of matrix
*NC_*	number of columns of matrix

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7.66.2 Constructor & Destructor Documentation

LocalMatrix ( )

Default constructor.

Constructs a matrix with `0` rows and `0` columns

LocalMatrix (Element * *el*, const SpMatrix< T_ > & *a*)

Constructor of a local matrix associated to element from a SpMatrix.

Parameters

in	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SpMatrix.

LocalMatrix (Element ∗ *el*, const SkMatrix< T_ > & *a*)

Constructor of a local matrix associated to element from a SkMatrix.
Parameters

in	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SkMatrix.

LocalMatrix (Element ∗ *el*, const SkSMatrix< T_ > & *a*)

Constructor of a local matrix associated to element from a SkSMatrix.
Parameters

in	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SkSMatrix.

7.66.3 Member Function Documentation

T_& operator() (size_t *i*, size_t *j*)

Operator `()` (Non constant version)
Returns entry at row `i` and column `j`.

T_ operator() (size_t *i*, size_t *j*) const

Operator `()` (Constant version)
Returns entry at row `i` and column `j`.

void Localize (Element ∗ *el*, const SpMatrix< T_ > & *a*)

Initialize matrix as element matrix from global SpMatrix.
Parameters

in	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SpMatrix. 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	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SkMatrix. 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	*el*	Pointer to Element
in	*a*	Global matrix as instance of class SkSMatrix. 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 witrh respect to matrix.
Returns the product $x^T A y$
Parameters

`in`	*x*	Left vector
`in`	*y*	Right vector

Returns

Resulting product

7.67 LocalVect< T_, N_ > Class Template Reference

Handles small size vectors like element vectors.

Public Member Functions

- LocalVect ()

  Default constructor.
- LocalVect (const T_ ∗a)

  Constructor using a C-array.
- LocalVect (const Element ∗el)

  Constructor using Element pointer.
- LocalVect (const Side ∗sd)

  Constructor using Side pointer.
- LocalVect (const LocalVect< T_, N_ > &v)

  Copy constructor.
- LocalVect (const Element ∗el, const Vect< T_ > &v, int opt=0)

  Constructor of an element vector from a global Vect instance.
- LocalVect (const 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 `nullptr` *otherwise.*

- Side ∗ Sd ()

  Return pointer to Side if vector was constructed using a side and `nullptr` *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.

7.67.1 Detailed Description

template<class T_, size_t N_>class OFELI::LocalVect< T_, N_ >

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_*	Data type (double, float, complex<double>, ...)
*N_*	Vector size

Author

Rachid Touzani

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7.67.2 Constructor & Destructor Documentation

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	*el*	Pointer to Element to localize
in	*v*	Global vector to localize
in	*opt*	Option for DOF treatment • = 0, Normal case [Default] • Any other value : only one DOF is handled (Local vector has as dimension number of degrees of freedom)

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	*el*	Reference to Element instance to localize
in	*v*	Global vector to localize
in	*opt*	Option for DOF treatment • = 0, Normal case [Default] • Any other value : only one DOF is handled (Local vector has as dimension number of degrees of freedom)

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	*sd*	Pointer to Side to localize
in	*v*	Global vector to localize
in	*opt*	Option for DOF treatment • = 0, Normal case [Default] • Any other value : only one DOF is handled (Local vector has as dimension number of degrees of freedom)

7.67.3 Member Function Documentation

void getLocal (const Element & *el*, const Vect< T_ > & *v*, int *type*)

Localize an element vector from a global Vect instance.

The constructed vector has local numbering of nodes This function is called by the constructor: `LocalVect(const Element *el, const Vect<T_> &v)`

Parameters

in	*el*	Pointer to Element to localize
in	*v*	Global vector to localize
in	*type*	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	*el*	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]

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]

T_& operator[ ] (size_t *i*)

Operator `[]` (Non constant version).

`v[i]` starts at `v[0]` to `v[size()-1]`

T_ operator[ ] (size_t *i*) const

Operator `[]` (Constant version).

`v[i]` starts at `v[0]` to `v[size()-1]`

T_& operator() (size_t *i*)

Operator `()` (Non constant version).

`v(i)` starts at `v(1)` to `v(size())`. `v(i)` is the same element as `v[i-1]`

T_ operator() (size_t *i*) const

Operator `()` (Constant version).

`v(i)` starts at `v(1)` to `v(size())` `v(i)` is the same element as `v[i-1]`

LocalVect<T_,N_>& operator= (const LocalVect< T_, N_ > & *v*)

Operator =

Copy a LocalVect instance to the current one

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

Operator =

Assign value `x` to all vector entries

LocalVect<T_,N_>& operator+= (const LocalVect< T_, N_ > & *v*)

Operator +=

Add vector `v` to this instance

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

Operator +=

Add constant `a` to vector entries

LocalVect<T_,N_>& operator-= (const LocalVect< T_, N_ > & *v*)

Operator -=
Subtract vector v from this instance

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

Operator -=
Subtract constant a from vector entries

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

Operator *=
Multiply vector by constant a

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

Operator /=
Divide vector by constant a

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

Return Dot (scalar) product of two vectors.
A typical use of this operator is `double a = (v,w)` where `v` and `w` are 2 instances of `LocalVect<double,n>`
Parameters

in	*v*	LocalVect instance by which the current instance is multiplied

7.68 LPSolver Class Reference

To solve a linear programming problem.

Public Types

- enum Setting {
  OBJECTIVE = 0,
  LE_CONSTRAINT = 1,
  GE_CONSTRAINT = 2,
  EQ_CONSTRAINT = 3 }

Public Member Functions

- LPSolver ()
  Default constructor.
- LPSolver (int nv, int nb_le, int nb_ge, int nb_eq)
  Constructor using Linear Program data.
- ~LPSolver ()
  Destructor.
- void setSize (int nv, int nb_le, int nb_ge, int nb_eq)
  Set optimization parameters.
- void set (Vect< real_t > &x)

vector of optimization variables

- void set (Setting opt, const Vect< real_t > &a, real_t b=0.0)

  Set optimization data.

- int run ()

  Run the linear program solver.

- real_t getObjective () const

  Return objective.

Friends

- ostream & operator<< (ostream &s, const LPSolver &os)

  Output class information.

7.68.1 Detailed Description

To solve a linear programming problem.
The Linear Program reads:

```
Minimise: d(1)*x(1) + ... + d(n)*x(n) + e
Subject to the constraints:
       A(i,1)*x(1) + ... + A(i,n)*x(n) <= a(i)  i=1,...,n_le
       B(i,1)*x(1) + ... + B(i,n)*x(n) >= b(i)  i=1,...,n_ge
       C(i,1)*x(1) + ... + C(i,n)*x(n) =  c(i)  i=1,...,n_eq
       x(i) >= 0, 1<=i<=n
```

Solution is held by the Simplex method Reference: "Numerical Recipes By W.H. Press, B. P. Flannery, S.A. Teukolsky and W.T. Vetterling, Cambridge University Press, 1986"
C-implementation copied from J-P Moreau, Paris

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7.68.2 Member Enumeration Documentation

enum Setting

Selects setting option: Objective or Constraints

Enumerator

OBJECTIVE Objective function coefficients

LE_CONSTRAINT 'Less or Equal' constraint coefficients

GE_CONSTRAINT 'Greater or Equal' constraint coefficients

EQ_CONSTRAINT 'Equality' constraint coefficients

7.68.3 Constructor & Destructor Documentation

LPSolver (int *nv*, int *nb_le*, int *nb_ge*, int *nb_eq*)

Constructor using Linear Program data.

Parameters

in	*nv*	Number of optimization variables
in	*nb_le*	Number of '<=' inequality constraints
in	*nb_ge*	Number of '>=' inequality constraints
in	*nb_eq*	Number of '=' equality constraints

7.68.4 Member Function Documentation

void setSize (int *nv*, int *nb_le*, int *nb_ge*, int *nb_eq*)

Set optimization parameters.
Parameters

in	*nv*	Number of optimization variables
in	*nb_le*	Number of '<=' inequality constraints
in	*nb_ge*	Number of '>=' inequality constraints
in	*nb_eq*	Number of '=' equality constraints

void set (Vect< real_t > & *x*)

vector of optimization variables
Parameters

in	*x*	Vector of optimization variables. Its size must be at least equal to number of optimization variables

void set (Setting *opt*, const Vect< real_t > & *a*, real_t *b* = `0.0`)

Set optimization data.

This function enables providing all optimization data. It has to be used for the objectice function and once for each constraint.
Parameters

in	*opt*	Option for data, to choose among enumerated values: • OBJECTIVE To set objective function to minimize • LE_CONSTRAINT To set a '<=' inequality constraint • GE_CONSTRAINT To set a '>=' inequality constraint • EQ_CONSTRAINT To set an equality constraint

in	*a*	Vector coefficients if the chosen function. If `opt==OBJECTIVE`, vector components are the coefficients multiplying the variables in the objective function. if `xx_CONSTRAINT`, vector components are the coefficients multiplying the variables in the corresponding constraint.
in	*b*	Constant value in the objective function or in a constraint. Its default value is 0.0

int run ( )

Run the linear program solver.
This function runs the linear programming solver using the Simplex algorithm

Returns

0 if process is complete, >0 otherwise

real_t getObjective ( ) const

Return objective.
Once execution is complete, this function returns optimal value of objective

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 consructor.
- 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 consructor.
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.

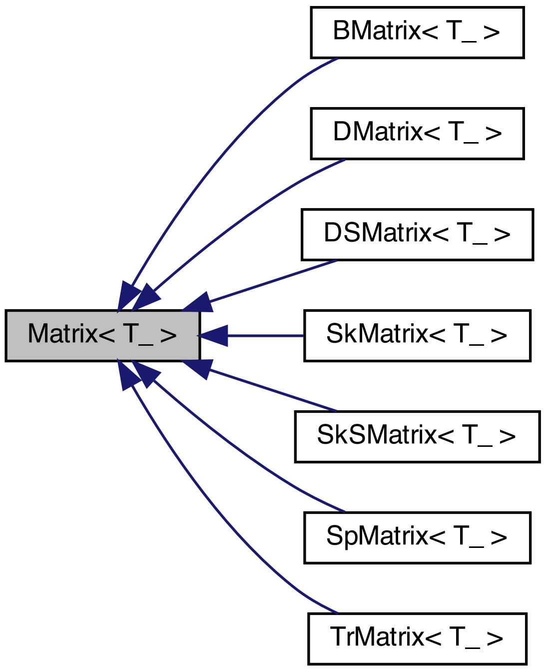
Returns

`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_ > &v, Vect< T_ > &w) 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 Side &sd, 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 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, bool fact=true)=0

  Solve the linear system.
- virtual int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)=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

$<T\_>$	Data type (real_t, float, complex<real_t>, ...)

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Rachid Touzani

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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 been modified

Reimplemented in DMatrix< T_ >, and DMatrix< real_t >.

T_ getDiag (size_t *k*) const

Return `k`-th diagonal entry of matrix.
First entry is given by **getDiag(1)**.

virtual void Axpy (T_ *a*, const Matrix< T_ > ∗ *x*) `[pure virtual]`

Add to matrix the product of a matrix by a scalar.
Parameters

in	a	Scalar to premultiply
in	x	Matrix by which `a` is multiplied. The result is added to current instance

Implemented in SpMatrix< T_ >, SpMatrix< real_t >, DSMatrix< T_ >, DSMatrix< real_t >, DMatrix< T_ >, DMatrix< real_t >, SkSMatrix< T_ >, SkMatrix< T_ >, TrMatrix< T_ >, BMatrix< T_ >, and BMatrix< real_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	*el*	Pointer to element instance
in	*a*	Element matrix as a C-array

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	*sd*	Pointer to side instance
in	*a*	Side matrix as a C-array instance

void Prescribe (Vect< T_ > & *b*, const Vect< T_ > & *u*, int *flag* = *0*)

Impose by a penalty method an essential boundary condition, using the Mesh instance provided by the constructor.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set**↩ **Penal**(..).

Parameters

in,out	*b*	Vect instance that contains right-hand side.
in	*u*	Vect instance that contains imposed valued at DOFs where they are to be imposed.
in	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

void Prescribe (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 **set**↩ **Penal**(..).

Parameters

in	*dof*	Degree of freedom for which a boundary condition is to be enforced
in	*code*	Code for which a boundary condition is to be enforced
in,out	*b*	Vect instance that contains right-hand side.
in	*u*	Vect instance that contains imposed valued at DOFs where they are to be imposed.

`in`	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

void Prescribe (Vect< T_ > & *b*, int *flag* = *0*)

Impose by a penalty method a homegeneous (=0) essential boundary condition.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set←Penal**(..).

Parameters

`in,out`	*b*	Vect instance that contains right-hand side.
`in`	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

void Prescribe (size_t *dof*, Vect< T_ > & *b*, const Vect< T_ > & *u*, int *flag* = *0*)

Impose by a penalty method an essential boundary condition when only one DOF is treated.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. This gunction is to be used if only one DOF per node is treated in the linear system. The penalty parameter is by default equal to 1.e20. It can be modified by member function setPenal.

Parameters

`in`	*dof*	Label of the concerned degree of freedom (DOF).
`in,out`	*b*	Vect instance that contains right-hand side.
`in`	*u*	Vect instance that conatins imposed valued at DOFs where they are to be imposed.
`in`	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

void PrescribeSide ( )

Impose by a penalty method an essential boundary condition when DOFs are supported by sides.

This member function modifies diagonal terms in matrix and terms in vector that correspond to degrees of freedom with nonzero code in order to impose a boundary condition. The penalty parameter is defined by default equal to 1.e20. It can be modified by member function **set←Penal**(..).

virtual int solve (Vect< T_ > & *b*, bool *fact* = *true*) `[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 DMatrix< T_ >, DMatrix< real_t >, SkSMatrix< T_ >, SkMatrix< T_ >, D←SMatrix< T_ >, DSMatrix< real_t >, BMatrix< T_ >, BMatrix< real_t >, and TrMatrix< T_ >.

virtual int solve (const Vect< T_ > & *b*, Vect< T_ > & *x*, bool *fact* = *true*) `[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	*b*	Vect instance that contains right-hand side
out	*x*	Vect instance that contains solution
in	*fact*	Set to `true` if factorization is to be performed, `false` if not. [Default: `true`]

Returns

- `0` if solution was normally performed
- `n` if the `n`-th pivot is null
  Solution is performed only is factorization has previously been invoked.

Implemented in SpMatrix< T_ >, SpMatrix< real_t >, DMatrix< T_ >, DMatrix< real_t >, SkSMatrix< T_ >, SkMatrix< T_ >, DSMatrix< T_ >, DSMatrix< real_t >, BMatrix< T_ >, BMatrix< real_t >, and TrMatrix< T_ >.

int FactorAndSolve (Vect< T_ > & *b*)

Factorize matrix and solve the linear system.

This is available only if the storage cass enables it.

Parameters

in,out	*b*	Vect instance that contains right-hand side on input and solution on output

int FactorAndSolve (const Vect< T_ > & *b*, Vect< T_ > & *x*)

Factorize matrix and solve the linear system.

This is available only if the storage class enables it.

Parameters

in	*b*	Vect instance that contains right-hand side
out	*x*	Vect instance that contains solution

Returns

- `0` if solution was normally performed
- `n` if the n-th pivot is nul

int isFactorized ( ) const

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_ >, SpMatrix< real_t >, SkSMatrix< T_ >, DMatrix< T_ >, DMatrix< real_t >, SkMatrix< T_ >, TrMatrix< T_ >, BMatrix< T_ >, BMatrix< real_t >, DS↩Matrix< T_ >, and DSMatrix< real_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_ >, SpMatrix< real_t >, DMatrix< T_ >, DMatrix< real_t >, SkSMatrix< T_ >, SkMatrix< T_ >, DSMatrix< T_ >, DSMatrix< real_t >, TrMatrix< T_ >, B↩Matrix< T_ >, and BMatrix< real_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_ >, SpMatrix< real_t >, DMatrix< T_ >, DMatrix< real_t >, SkSMatrix< T_ >, SkMatrix< T_ >, DSMatrix< T_ >, DSMatrix< real_t >, TrMatrix< T_ >, B↩Matrix< T_ >, and BMatrix< real_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*	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*	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 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 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.
- 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, EL↩ EMENT_DOF SIDE_DOF.
- void Deform (const Vect< real_t > &u, real_t rate=0.2)
  Deform mesh according to a displacement vector.
- 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 refenrece to node with label `i`
- Element ∗ getPtrElement (size_t i) const
  Return pointer to element with label `i`
- Element & getElement (size_t i) const

Return reference to element with label i

- Side ∗ getPtrSide (size_t i) const

  Return pointer to side with label i

- Side & getSide (size_t i) const

  Return reference to side with label i

- Edge ∗ getPtrEdge (size_t i) const

  Return pointer to edge with label i

- Edge & getEdge (size_t i) const

  Return reference to edge with label i

- size_t getNodeLabel (size_t i) const

  Return label of i-th node.

- size_t getElementLabel (size_t i) const

  Return label of i-th element.

- size_t getSideLabel (size_t i) const

  Return label of i-th side.

- size_t getEdgeLabel (size_t i) const

  Return label of i-th edge.

- void topNode () const

  Reset list of nodes at its top position (Non constant version)

- void topBoundaryNode () const

  Reset list of boundary nodes at its top position (Non constant version)

- void topMarkedNode () const

  Reset list of marked nodes at its top position (Non constant version)

- void topElement () const

  Reset list of elements at its top position (Non constant version)

- void topSide () const

  Reset list of sides at its top position (Non constant version)

- void topBoundarySide () const

  Reset list of boundary sides at its top position (Non constant version)

- void topInternalSide () const

  Reset list of intrenal sides at its top position (Non constant version)

- void topEdge () const

  Reset list of edges at its top position (Non constant version)

- void topBoundaryEdge () const

  Reset list of boundary edges at its top position (Non constant version)

- Node ∗ getNode () const

  Return pointer to current node and move to next one (Non constant version)

- Node ∗ getBoundaryNode () const

  Return pointer to current boundary node and move to next one (Non constant version)

- Node ∗ getMarkedNode () const

  Return pointer to current marked node and move to next one (Non constant version)

- Element ∗ getElement () const

  Return pointer to current element and move to next one (Non constant version)

- Element ∗ getActiveElement () const

  Return pointer to current element and move to next one (Non constant version)

- Side ∗ getSide () const

Return pointer to current side and move to next one (Non constant version)

- Side ∗ getBoundarySide () const

  Return pointer to current boundary side and move to next one (Non constant version)
- Side ∗ getInternalSide () const

  Return pointer to current internal side and move to next one (Non constant version)
- Edge ∗ getEdge () const

  Return pointer to current edge and move to next one (Non constant version)
- Edge ∗ getBoundaryEdge () const

  Return pointer to current boundary edge and move to next one (Non constant version)
- int getShape () const

  Determine shape of elements Return Shape index (see enum ElementShape) if all elements have the same shape, 0 if not.
- Element ∗ operator() (size_t i) const

  Operator () : Return pointer to i-th element.
- Node ∗ operator[ ] (size_t i) const

  Operator [] : Return pointer to i-th node.
- size_t operator() (size_t i, size_t n) const

  Operator () : Return pointer to i-th node of n-th element.
- Mesh & operator= (Mesh &ms)

  Operator = : Assign a Mesh instance.

Friends

- void Refine (Mesh &in_mesh, Mesh &out_mesh)

  Refine mesh. Subdivide each triangle into 4 subtriangles. This member function is valid for 2-D triangular meshes only.

7.71.1 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.

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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	*file*	File containing mesh data. The extension of the file yields the file format: The extension .m implies OFELI file format and .msh implies GMSH msh file.
in	*bc*	Flag to remove (true) or not (false) imposed Degrees of Freedom [default: false]
in	*opt*	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	*nb_dof*	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	*xmin*	Value of xmin
in	*xmax*	Value of xmax
in	*nb_el*	Number of elements to generate
in	*p*	Degree of finite element polynomial (Default = 1)
in	*nb_dof*	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	*g*	Grid instance
in	*opt*	Optional value to say which type of elements to generate • TRIANGLE: Mesh elements are triangles • QUADRILATERAL: Mesh elements are quadrilaterals [default]

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	*g*	Grid instance
in	*shape*	Value to say which type of elements to generate • TRIANGLE: Mesh elements are triangles • QUADRILATERAL: Mesh elements are quadrilaterals [default]
in	*opt*	This argument can take any value. It is here only to distinguish from the other constructor using Grid 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	*xmin*	Minimal coordinate
in	*xmax*	Maximal coordinate
in	*ne*	Number of elements
in	*c1*	Code for the first node (x=xmin)
in	*c2*	Code for the last node (x=xmax)
in	*p*	Degree of approximation polynomial [Default: 1].
in	*nb_dof*	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 (xmin,xmax)x(ymin,ymax)
Parameters

in	*xmin*	Minimal x-coordinate
in	*xmax*	Maximal x-coordinate
in	*ymin*	Minimal y-coordinate
in	*ymax*	Maximal y-coordinate
in	*nx*	Number of subintervals on the x-axis
in	*ny*	Number of subintervals on the y-axis
in	*cx0*	Code for nodes generated on the line x=x0 if >0, for sides on this line if <0
in	*cxN*	Code for nodes generated on the line x=xN if >0, for sides on this line if <0
in	*cy0*	Code for nodes generated on the line y=y0 if >0, for sides on this line if <0
in	*cyN*	Code for nodes generated on the line y=yN if >0, for sides on this line if <0
in	*opt*	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: TRIANG↵LE or QUADRILATERAL, with obvious meaning.
in	*nb_dof*	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 parallepiped (xmin,xmax)x(ymin,ymax)x(zmin,zmax)

Parameters

in	*xmin*	Minimal x-coordinate
in	*xmax*	Maximal x-coordinate
in	*ymin*	Minimal y-coordinate
in	*ymax*	Maximal y-coordinate
in	*zmin*	Minimal z-coordinate
in	*zmax*	Maximal z-coordinate
in	*nx*	Number of subintervals on the x-axis
in	*ny*	Number of subintervals on the y-axis
in	*nz*	Number of subintervals on the z-axis
in	*cx0*	Code for nodes generated on the line x=xmin if >0, for sides on this line if <0
in	*cxN*	Code for nodes generated on the line x=xmax if >0, for sides on this line if <0
in	*cy0*	Code for nodes generated on the line y=ymin if >0, for sides on this line if <0
in	*cyN*	Code for nodes generated on the line y=ymax if >0, for sides on this line if <0
in	*cz0*	Code for nodes generated on the line z=zmin if >0, for sides on this line if <0
in	*czN*	Code for nodes generated on the line z=zmax if >0, for sides on this line if <0
in	*opt*	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: HEXAH←EDRON or TETRAHEDRON, with obvious meaning.
in	*nb_dof*	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	*m*	Initial mesh from which the submesh is extracted
in	*x_bl*	Coordinate of bottom left vertex of the rectangle
in	*x_tr*	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	*mesh*	Initial mesh from which the submesh is extracted
in	*opt*	Type of DOF support: To choose among enumerated values `NO`↩ `DE_DOF`, `SIDE_DOF` or `ELEMENT_DOF`.
in	*dof1*	Label of first degree of freedom to select to the output mesh
in	*dof2*	Label of last degree of freedom to select to the output mesh
in	*bc*	Flag to remove (`true`) or not (`false`) imposed Degrees of Freedom [Default: `false`]

Mesh (const Mesh & *ms*)

Copy Constructor.
Parameters

in	*ms*	Mesh instance to copy

7.71.3 Member Function Documentation

void setDim (size_t *dim*)

Define space dimension. Normally, between 1 and 3.
Parameters

in	*dim*	Space dimension to set (must be between 1 and 3)

void Add (Node ∗ *nd*)

Add a node to mesh.
Parameters

in	*nd*	Pointer to Node to add

void Add (Element ∗ *el*)

Add an element to mesh.
Parameters

in	*el*	Pointer to Element to add

void Add (Side ∗ *sd*)

Add a side to mesh.
Parameters

in	*sd*	Pointer to Side to add

void Add (Edge ∗ *ed*)

Add an edge to mesh.

Parameters

in	*ed*	Pointer to Edge to add

Mesh& operator*= (real_t *a*)

Operator *=

Rescale mesh coordinates by myltiplying by a factor

Parameters

in	*a*	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	*mesh_file*	Mesh 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	*mesh_file*	Mesh file name
in	*ff*	File format: Integer to chose among enumerated values: `OFELI_FF`, `GMSH`, `MATLAB`, `EASYMESH`, `GAMBIT`, `BAMG`, `NETGEN`, `TRIANGLE_FF`
in	*nb_dof*	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	*opt*	DOF type: • `NODE_DOF`: Degrees of freedom are supported by nodes • `SIDE_DOF`: Degrees of freedom are supported by sides • `EDGE_DOF`: Degrees of freedom are supported by edges • `ELEMENT_DOF`: Degrees of freedom are supported by elements

in	*nb_nodes*	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	*nb_dof*	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 renumbers 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	*x*	Coordinates of point to define

size_t NumberEquations (size_t *dof* = 0)

Renumber Equations.
Parameters

in	*dof*	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	*dof*	Label of degree of freedom for which numbering is performed.
in	*c*	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↩ ::getNeigborElement)

void setMaterial (int *code*, const string & *mname*)

Associate material to code of element.

Parameters

in	*code*	Element code for which material is assigned
in	*mname*	Name of material

void Reorder (size_t *m* = GRAPH_MEMORY)

Renumber mesh nodes according to reverse Cuthill Mc Kee algorithm.
Parameters

in	*m*	Memory size needed for matrix graph (default value is GRAPH↩ _MEMORY, see OFELI_Config.h)

void Add (size_t *num*, real_t ∗ *x*)

Add a node by giving its label and an array containing its coordinates.
Parameters

in	*num*	Label of node to add
in	*x*	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	*label*	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	*label*	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	*label*	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	*nd*	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	*el*	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	*sd*	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	*ed*	Pointer to edge to delete

void RenumberNode (size_t *n1*, size_t *n2*)

Renumber a node.
Parameters

in	*n1*	Old label
in	*n2*	New label

void RenumberElement (size_t *n1*, size_t *n2*)

Renumber an element.
Parameters

in	*n1*	Old label
in	*n2*	New label

void RenumberSide (size_t *n1*, size_t *n2*)

Renumber a side.
Parameters

in	*n1*	Old label
in	*n2*	New label

void RenumberEdge (size_t *n1*, size_t *n2*)

Renumber an edge.

Parameters

in	*n1*	Old label
in	*n2*	New label

void setList (const std::vector< Node ∗ > & *nl*)

Initialize list of mesh nodes using the input vector.

Parameters

in	*nl*	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	*el*	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	*sl*	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	*sx*	Factor to multiply by x coordinates
in	*sy*	Factor to multiply by y coordinates [Default: `sx`]
in	*sz*	Factor to multiply by z coordinates [Default: `sx`]

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	*g*	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	*nd*	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	*el*	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	*sd*	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 Deform (const Vect< real_t > & *u*, real_t *rate* = `0.2`)

Deform mesh according to a displacement vector.

This function modifies node coordinates according to given displacement vector and given rate

Parameters

in	*u*	Displacement vector
in	*rate*	Maximal rate of deformation of resulting mesh. Its default value is 0.2, *i.e.* The resulting mesh has a maximum of deformation rate of 20%

void put (const string & *mesh_file*) const

Write mesh data on file.

Parameters

in	*mesh_file*	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	*mesh_file*	Mesh file name If the extension is '.m', the output file is an OFELI 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	*nl*	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	*el*	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	*sl*	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*	Node index

size_t getElementLabel (size_t *i*) const

Return label of `i`-th element.
Parameters

in	*i*	Element index

size_t getSideLabel (size_t *i*) const

Return label of `i`-th side.
Parameters

in	*i*	Side index

size_t getEdgeLabel (size_t *i*) const

Return label of `i`-th edge.
Parameters

in	*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 is 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	*in_mesh*	Input mesh
out	*out_mesh*	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 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 incoporation of Bamg in the OFELI package

Author

Rachid Touzani

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7.72.2 Constructor & Destructor Documentation

MeshAdapt (Mesh & *ms*)

Constructor using initial mesh.

Parameters

`in`	*ms*	Reference to initial mesh

MeshAdapt (Domain & *dom*)

Constructor using a reference to class Domain.

Parameters

`in`	*dom*	Reference to Domain 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	*r*	Ratio value.

Note

If `r` is 0 then no smoothing is performed, if `r` lies in `[1.1,10]` then the smoothing changes the metric such that the largest geometrical progression (speed of mesh size variation in mesh is bounded by `r`) (by default no smoothing)

void setNoScaling ( )

Do not scale solution before metric computation.
By default, solution is scaled (between 0 and 1)

void setNoKeep ( )

Do not keep old vertices.
By default, old vertices are kept

void getSolutionbb (string *rbb*)

Read solution defined on the background mesh in `bb` file.
Solution is interpolated on created mesh

void getSolutionBB (string *rBB*)

Read solution defined on the background mesh in `BB` file.
Solution is interpolated on created mesh

void getSolution (Vect< real_t > & *u*, int *is* = *1*)

Get the interpolated solution on the new mesh.
The solution must have been saved on an output bb file
Parameters

out	*u*	Vector that contains on output the obtained solutions. This vector is resized before being initialized
in	*is*	[Default: `1`]

void setTheta (real_t *theta*)

Set angular limit for a corner (in degrees)
The angle is defined from 2 normals of 2 consecutive edges

void saveMbb (string *file*, const Vect< real_t > & *u*)

Save a solution in metric file.

Parameters

in	*file*	File name where the metric is stored
in	*u*	Solution vector to store

int run ( )

Run adaptation process.

Returns

Return code:

- = 0: Adaptation has been normally completed
- = 1: An error occured

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 occured

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

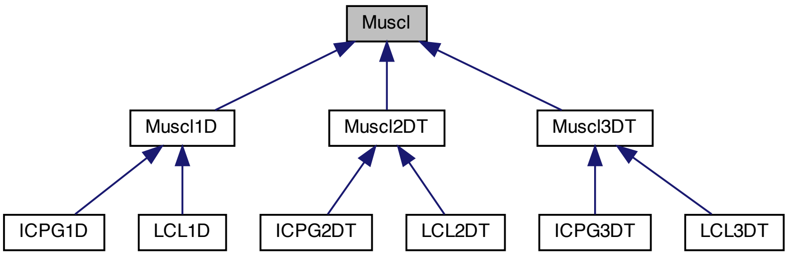
Return code:

- = 0: Adaptation has been normally completed
- = 1: An error occured

7.73 Muscl Class Reference

Parent class for hyperbolic solvers with Muscl scheme.

Inheritance diagram for Muscl:



Public Types

- enum Method {
  FIRST_ORDER_METHOD = 0,
  MULTI_SLOPE_Q_METHOD = 1,
  MULTI_SLOPE_M_METHOD = 2 }

  Enumeration for flux choice.
- enum Limiter {
  MINMOD_LIMITER = 0,
  VANLEER_LIMITER = 1,
  SUPERBEE_LIMITER = 2,
  VANALBADA_LIMITER = 3,
  MAX_LIMITER = 4 }

  Enumeration of flux limiting methods.
- enum SolverType {
  ROE_SOLVER = 0,
  VFROE_SOLVER = 1,
  LF_SOLVER = 2,
  RUSANOV_SOLVER = 3,
  HLL_SOLVER = 4,
  HLLC_SOLVER = 5,
  MAX_SOLVER = 6 }

  Enumeration of various solvers for the Riemann problem.

Public Member Functions

- Muscl (Mesh &m)

  Constructor using mesh instance.
- virtual ~Muscl ()

  Destructor.
- void setTimeStep (real_t dt)

  Assign time step value.
- real_t getTimeStep () const

  Return time step value.
- void setCFL (real_t CFL)

Assign CFL value.

- real_t getCFL () const

  Return CFL value.
- void setReferenceLength (real_t dx)

  Assign reference length value.
- real_t getReferenceLength () const

  Return reference length.
- Mesh & getMesh () const

  Return reference to Mesh instance.
- void setVerbose (int v)

  Set verbosity parameter.
- bool setReconstruction (const Vect< real_t > &U, Vect< real_t > &LU, Vect< real_t > &RU, size_t dof)

  Function to reconstruct by the Muscl method.
- void setMethod (const Method &s)

  Choose a flux solver.
- void setSolidZoneCode (int c)

  Choose a code for solid zone.
- bool getSolidZone () const

  Return flag for presence of solid zones.
- int getSolidZoneCode () const

  Return code of solid zone, 0 if this one is not present.
- void setLimiter (Limiter l)

  Choose a flux limiter.

7.73.1 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	*dt*	Time step value

void setCFL (real_t *CFL*)

Assign CFL value.

Parameters

in	*CFL*	Value of CFL

void setReferenceLength (real_t *dx*)

Assign reference length value.

Parameters

in	*dx*	Value of reference length

void setVerbose (int *v*)

Set verbosity parameter.

Parameters

in	*v*	Value of verbosity parameter

bool setReconstruction (const Vect< real_t > & *U*, Vect< real_t > & *LU*, Vect< real_t > & *RU*, size_t *dof*)

Function to reconstruct by the Muscl method.

Parameters

in	*U*	Field to reconstruct
out	*LU*	Left gradient vector
out	*RU*	Right gradient vector
in	*dof*	Label of dof to reconstruct

void setMethod (const Method & *s*)

Choose a flux solver.

Parameters

in	*s*	Solver to choose

void setLimiter (Limiter *l*)

Choose a flux limiter.

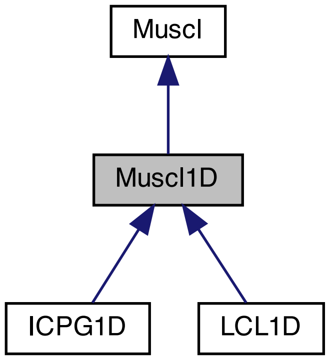
Parameters

in	*l*	Limiter to choose

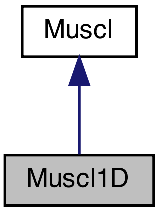
7.74 Muscl1D Class Reference

Class for 1-D hyperbolic solvers with Muscl scheme.

Inheritance diagram for Muscl1D:



Collaboration diagram for Muscl1D:



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.

Additional Inherited Members

7.74.1 Detailed Description

Class for 1-D hyperbolic solvers with Muscl scheme.

Author

S. Clain, V. Clauzon

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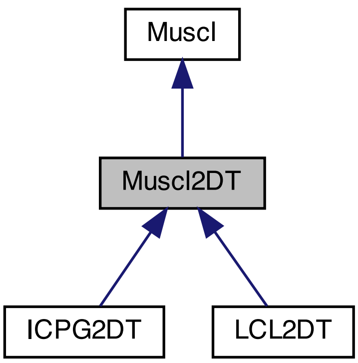
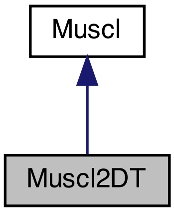
7.75 Muscl2DT Class Reference

Class for 2-D hyperbolic solvers with Muscl scheme.

Inheritance diagram for Muscl2DT:



Collaboration diagram for Muscl2DT:



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.

Protected Member Functions

- void Initialize ()

  Construction of normals to sides.

Additional Inherited Members

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 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	*U*	Field to reconstruct
out	*LU*	Left gradient vector
out	*RU*	Right gradient vector
in	*dof*	Label of dof to reconstruct

void Initialize ( ) `[protected]`

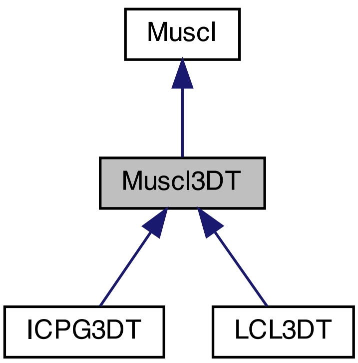
Construction of normals to sides.

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.

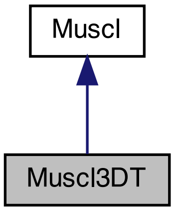
7.76 Muscl3DT Class Reference

Class for 3-D hyperbolic solvers with Muscl scheme using tetrahedra.

Inheritance diagram for Muscl3DT:



Collaboration diagram for Muscl3DT:



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.

Additional Inherited Members

7.76.1 Detailed Description

Class for 3-D hyperbolic solvers with Muscl scheme using tetrahedra.

Author

S. Clain, V. Clauzon

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7.76.2 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	*U*	Field to reconstruct
out	*LU*	Left gradient vector
out	*RU*	Right gradient vector
in	*dof*	Label of dof to reconstruct

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

mesh	Reference to Mesh 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	*x*	Vector of variables
in	*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 (Mesh &mesh)

  Constructor using mesh instance.
- virtual ~MyOpt ()

Destructor.

- virtual real_t Objective (Vect< real_t > &x)=0

  Virtual member function to define objective.
- virtual void Gradient (Vect< real_t > &x, Vect< real_t > &g)

  Virtual member function to define gradient vector of objective.
- void setEquation (Equa *eq)

  Define equation instance.
- Equa * getEquation () const

  Get pointer to equation instance.

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 (Mesh & *mesh*)

Constructor using mesh instance.

Parameters

mesh	Reference to Mesh instance

7.78.3 Member Function Documentation

virtual real_t Objective (Vect< real_t > & *x*) `[pure virtual]`

Virtual member function to define objective.

Parameters

in	*x*	Vector of optimization variables

Returns

Value of objective

virtual void Gradient (Vect< real_t > & *x*, Vect< real_t > & *g*) `[virtual]`

Virtual member function to define gradient vector of objective.

Parameters

in	*x*	Vector of optimization variables
out	*g*	Gradient vector

void setEquation (Equa ∗ *eq*)

Define equation instance.
Parameters

in	*eq*	Pointer to equation instance

Remarks

This member function is to be invoked in the user class defining the optimization problem

Equa∗ getEquation ( ) const

Get pointer to equation instance.

Returns

Pointer to equation instance

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 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 setNbEq (size_t nb_eq)

  Define number of equations.

- 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 pzrtial derivative of function for which zero is sought (case of many equations)
- void setPDE (Equa &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	*nl*	Choose an iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: `BISECT`↩ `ION`, `REGULA_FALSI` or `NEWTON`.
in	*nb_eq*	Number of equations [Default: `1`]

NLASSolver (real_t & *x*, NonLinearIter *nl* = *`NEWTON`* **)**

Constructor defining a one-variable problem.

Parameters

in	*x*	Variable containing on input initial guess and on output solution, if convergence is achieved
in	*nl*	Iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: `BISECTION`, `REGULA_F`↩ `ALSI` or `NEWTON`.

NLASSolver (Vect< real_t > & *x*, NonLinearIter *nl* = *`NEWTON`* **)**

Constructor defining a multi-variable problem.

Parameters

in	*x*	Variable containing on input initial guess and on output solution, if convergence is achieved
in	*nl*	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	*my_nlas*	Reference to instance of user defined class. This class inherits from abstract class MyNLAS. It must contain the member function `Vect<double>` Function(const Vect<double>& x) which returns the value of the nonlinear function, as a vector, for a given solution vector `x`. The user defined class must contain, if the iterative scheme requires it the member function `Vect<double>` Gradient(const Vect<real_t>& x) which returns the gradient as a `n*n` vector, each index (i,j) containing the j-th partial derivative of the i-th function.

in	*nl*	Iterative procedure to solve the nonlinear system of equations: To be chosen among the enumerated values: `BISECTION`, `REGULA_F`↩`ALSI` or `NEWTON`.

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	*f*	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	*f*	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	*g*	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	*g*	Function given as a function of many variables, stored in an input vector. and returns a `n*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	*exp*	Regular expression defining the function using the symbol `x` as a variable

void setDf (string *exp*, int *i* = *1*, int *j* = *1*)

Set pzrtial derivative of function for which zero is sought (case of many equations)

Parameters

in	*exp*	Regular expression defining the partial derivative. In this expression, the variables are `x1`, `x2`, ... `x10` (up to 10 variables)
in	*i*	Component of function [Default: =1]
in	*j*	Index of the partial derivative [Default: =1]

void setPDE (Equa & *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 Equa.

Parameters

in	*eq*	Pointer to equation instance

void setInitial (Vect< real_t > & *u*)

Set initial guess for the iterations.

Parameters

in	*u*	Vector containing initial guess for the unknown

void setInitial (real_t & *x*)

Set initial guess for a unique unknown.

Parameters

in	*x*	Rference to value of initial guess

void setInitial (real_t *a*, real_t *b*)

Set initial guesses bisection or Regula falsi algorithms.

Parameters

in	*a*	Value of first initial guess
in	*b*	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	*u*	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	*label*	Label of node
in	*x*	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	*dof*	DOF index
in	*code*	Code to assign to DOF

void setCode (const vector< int > & *code*)

Define codes for all node DOFs.

Parameters

in	*code*	vector instance that contains code for each DOF of current node

void setCode (int * *code*)

Define codes for all node DOFs.

Parameters

in	*code*	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	*exp*	Boolean algebraic expression as required by `fparser`
in	*code*	Code to assign to node if the algebraic expression is true
in	*dof*	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*	Coordinate index (1..3)
in	*x*	Coordinate value

void DOF (size_t *i*, size_t *dof*)

Define label of DOF.
Parameters

in	*i*	DOF index
in	*dof*	Label of DOF

void setDOF (size_t & *first_dof*, size_t *nb_dof*)

Define number of DOF.
Parameters

in,out	*first_dof*	Label of the first DOF in input that is actualized
in	*nb_dof*	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	*dof*	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	*code*	Code that nodes share
in	*dof*	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	*code*	Code of nodes to exclude
in	*dof*	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

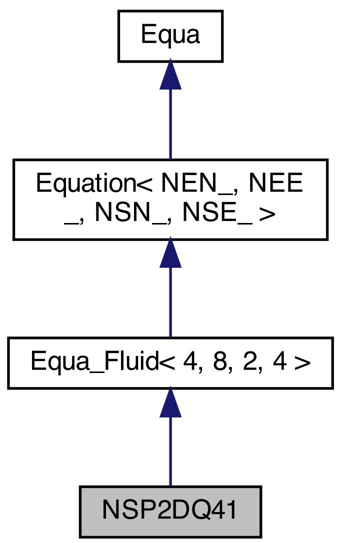
in	*x*	x-coordinate that share the selected nodes
in	*y*	y-coordinate that share the selected nodes [Default: `ANY`]
in	*z*	z-coordinate that share the selected nodes [Default: `ANY`]

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);

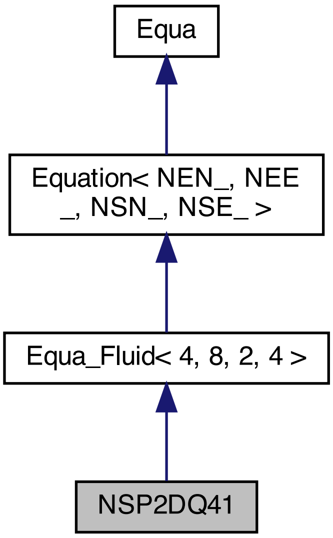
7.82 NSP2DQ41 Class Reference

Builds finite element arrays for incompressible Navier-Stokes equations in 2-D domains using Q_1/P_0 element and a penaly formulation for the incompressibility condition.

Inheritance diagram for NSP2DQ41:



Collaboration diagram for NSP2DQ41:



Public Member Functions

- NSP2DQ41 (Mesh &ms)
  Constructor using mesh data.
- NSP2DQ41 (Mesh &ms, Vect< real_t > &u)
  Constructor using mesh data and velocity vector.
- ∼NSP2DQ41 ()
  Destructor.
- void setPenalty (real_t lambda)
  Define penalty parameter.
- void setInput (EqDataType opt, Vect< real_t > &u)
  Set equation input data.
- void Periodic (real_t coef=1.e20)
  Add contribution of periodic boundary condition (by a penalty technique).
- void build ()
  Build the linear system of equations.
- int runOneTimeStep ()
  Run one time step.

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 penaly formulation for the incompressibility condition.

Author

Rachid Touzani

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7.82.2 Constructor & Destructor Documentation

NSP2DQ41 (Mesh & *ms*)

Constructor using mesh data.

Parameters

in	*ms*	Mesh instance

NSP2DQ41 (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh data and velocity vector.

Parameters

in	*ms*	Mesh instance
in,out	*u*	Velocity vector

7.82.3 Member Function Documentation

void setPenalty (real_t *lambda*)

Define penalty parameter.

Penalty parameter is used to enforce the incompressibility constraint

Parameters

in	*lambda*	Penaly parameter: Large value [Default: `1.e07`]

void setInput (EqDataType *opt*, Vect< real_t > & *u*)

Set equation input data.

Parameters

in	*opt*	Parameter that selects data type for input. This parameter is to be chosen in the enumerated variable EqDataType
in	*u*	Vect instance that contains input vector data List of data types contains `INITIAL_FIELD`, `BOUNDARY_CONDITION_DATA`, `SOURCE_DATA` or `FLUX` with obvious meaning

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 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.

int runOneTimeStep ( )

Run one time step.
This function performs one time step, once a time integration scheme has been selected.

7.83 ODESolver Class Reference

To solve a system of ordinary differential equations.

Public Member Functions

- ODESolver ()

  Default constructor.
- ODESolver (size_t nb_eq)

  Constructor providing the number of equations.
- 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 n)

  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 setLinear ()

  Claim that ODE is linear.
- void setF (string f)

  Set time derivative, given as an algebraic expression, for a nonlinear ODE.
- void setF (string f, int i)

  Set time derivative, given as an algebraic expression, for a nonlinear ODE.

- void setDF (string df, int i, int j)

  Set time derivative of the function defining the ODE.
- void setdFdt (string df, int i)

  Set time derivative 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-oder system of differential equations.
- void setInitial (real_t u, int i)

  Set initial condition for a first-oder 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 Newmarxk 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 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.
- size_t getNbEq () const

  Return number of equations.
- 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:
  A_1(t)u'(t) + A_0(t)u(t) = f(t)
- A linear system of differential equations of the second-order:
  A_2(t)u''(t) + A_1(t)u'(t) + A_0(t)u(t) = f(t)
- A system of ordinary differential equations of the form:
  u'(t) = f(t,u(t))

The following time integration schemes can be used:

- Forward Euler scheme (value: *FORWARD_EULER*) for first-order systems
- Backward Euler scheme (value: *BACKWARD_EULER*) for first-order linear systems
- Crank-Nicolson (value: *CRANK_NICOLSON*) for first-order linear systems
- Heun (value: *HEUN*) for first-order systems
- 2nd Order Adams-Bashforth (value: *AB2*) for first-order systems
- 4-th order Runge-Kutta (value: *RK4*) for first-order systems
- 2nd order Backward Differentiation Formula (value: *BDF2*) for linear first-order systems
- Newmark (value: *NEWMARK*) for linear second-order systems with constant matrices

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	*s*	Choice of the scheme: To be chosen in the enumerated variable *Scheme* (see the presentation of the class)
in	*time_step*	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	*final_time*	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	*nb_eq*	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	*s*	Choice of the scheme: To be chosen in the enumerated variable *Scheme* (see the presentation of the class)
in	*time_step*	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	*final_time*	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 *n*)

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 setLinear ( )

Claim that ODE is linear.

Claim that the defined ODE (or system of ODEs) is linear

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

Parameters

`in`	*f*	Expression of the function

void setF (string *f*, int *i*)

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))
This function is to be used for the `i`-th equation of a system of ODEs

Parameters

`in`	*f*	Expression of the function
`in`	*i*	Index of equation. Must be not larger than the number of equations

void setDF (string *df*, int *i*, int *j*)

Set time derivative 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 setdFdt (string *df*, int *i*)

Set time derivative 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*	Value of right-hand side

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-oder system of differential equations.
Parameters

in	*u*	Vector containing initial condition for the unknown

void setInitial (real_t *u*, int *i*)

Set initial condition for a first-oder system of differential equations.
Parameters

in	*u*	Initial condition for an unknown
in	*i*	Index of 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 somtimes 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 somtimes 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	*a0*	Reference to vector in front of the 0-th order term (no time derivative)
in	*a1*	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	*a0*	Reference to vector in front of the 0-th order term (no time derivative)
in	*a1*	Reference to vector in front of the 1-st order term (first time derivative)
in	*a2*	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	*b*	Vect 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 Newmarxk scheme.
Parameters

in	*beta*	Parameter beta [Default: `0.25`]
in	*gamma*	Parameter gamma [Default: `0.5`]

void setConstantMatrix ( )

Say that matrix problem is constant.
This is useful if the linear system is solved by a factorization method but has no effect otherwise

void setNonConstantMatrix ( )

Say that matrix problem is variable.
This is useful if the linear system is solved by a factorization method but has no effect otherwise

void setLinearSolver (Iteration *s* = DIRECT_SOLVER, Preconditioner *p* = DIAG_PREC)

Set linear solver data.
Parameters

in	*s*	Solver identification parameter. To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOLVER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVER [Default: `DIRECT_SOLVER`]
in	*p*	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 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	*max_it*	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	*toler*	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	*opt*	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*	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

Author

Rachid Touzani

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7.85 OptSolver Class Reference

To solve an optimization problem with bound constraints.

Public Types

- enum OptMethod {
  GRADIENT = 0,
  TRUNCATED_NEWTON = 1,
  SIMULATED_ANNEALING = 2,
  NELDER_MEAD = 3,
  NEWTON = 4 }
  Choose optimization algorithm.

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.
- void set (Vect< real_t > &x)

  Set Solution vector.
- 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 setHessian (string exp, int i=1, int j=1)

  Define an entry of the Hessian matrix.
- void setIneqConstraint (string exp, real_t penal=1./OFELI_TOLERANCE)

  Impose an inequatity constraint by a penalty method.
- void setEqConstraint (string exp, real_t penal=1./OFELI_TOLERANCE)

  Impose an equatity constraint by a penalty method.
- void setObjective (function< real_t(real_t)> f)

  Define the objective function by a user defined one-variable function.
- void setObjective (function< real_t(Vect< real_t >)> f)

  Define the objective function by a user defined multi-variable function.
- void setGradient (function< real_t(real_t)> f)

  Define the derivative of the objective function by a user defined function.
- void setGradient (function< Vect< real_t >(Vect< real_t >)> f)

  Define the gradient of the objective function by a user defined function.
- void setOptClass (MyOpt &opt)

  Choose user defined optimization class.
- void setLowerBound (size_t i, real_t lb)

  Define lower bound for a particular optimization variable.
- void setUpperBound (size_t i, real_t ub)

  Define upper bound for a particular optimization variable.
- void setEqBound (size_t i, real_t b)

  Define value to impose to a particular optimization variable.
- 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 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)

  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

Rachid Touzani

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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

NEWTON Newton's 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`	*opt*	Reference to instance of user defined optimization class. This class inherits from abstract class MyOpt. It must contain the member function `double Objective(Vect<double> &x)` 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 `Gradient(Vect<double> &x, Vect<double> &g)` 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	*m*	Enumerated value to choose the optimization algorithm to use. Must be chosen among the enumerated values: • GRADIENT: Gradient steepest descent method with projection for bounded constrained problems • 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). • 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. • 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. ONeill (Algorithm AS 47: Function Minimization Using a Simplex Procedure, Applied Statistics, Volume 20, Number 3, 1971, pages 338-345).

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	*bc*	Vector containing the values to impose on degrees of freedom. This vector must have been constructed using the Mesh 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	*exp*	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	*exp*	Regular expression defining the objective function
in	*i*	Component of gradient [Default: 1]

void setHessian (string *exp*, int *i* = *1*, int *j* = *1*)

Define an entry of the Hessian matrix.
Parameters

in	*exp*	Regular expression defining the Hessian matrix entry
in	*i*	*i*-th row of Hessian matrix [Default: 1]
in	*j*	*j*-th column of Hessian matrix [Default: 1]

void setIneqConstraint (string *exp*, real_t *penal* = *1./*OFELI_TOLERANCE)

Impose an inequatity constraint by a penalty method.

The constraint is of the form F(x) <= 0 where F is any function of the optimization variable vector `v`
Parameters

in	*exp*	Regular expression defining the constraint (the function `F`
in	*penal*	Penalty parameter (large number) [Default: `1./DBL_EPSILON`]

void setEqConstraint (string *exp*, real_t *penal* = *1./*OFELI_TOLERANCE)

Impose an equatity constraint by a penalty method.

The constraint is of the form F(x) = 0 where F is any function of the optimization variable vector `v`
Parameters

in	*exp*	Regular expression defining the constraint (the function `F`
in	*penal*	Penalty parameter (large number) [Default: `1./DBL_EPSILON`]

void setObjective (function< real_t(real_t)> *f*)

Define the objective function by a user defined one-variable function.

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	*f*	Function given as a function of one real variable which is the optimization variable and returning the objective value. This function can be defined by the calling program as a C-function and then cast to an instance of class function

void setObjective (function< real_t(Vect< real_t >)> *f*)

Define the objective function by a user defined multi-variable function.

This function can be used in the case where a user defined function is to be given. To be used in the multivariable case.

Parameters

in	*f*	Function given as a function of many real variables and returning the objective value. 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)> *f*)

Define the derivative of the objective function by a user defined function.
Parameters

in	*f*	Function given as a function of a real variable and returning the derivative of the objective value. 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 >)> *f*)

Define the gradient of the objective function by a user defined function.
Parameters

in	*f*	Function given as a function of a many real variables and returning the partial derivatives of the objective value. This function can be defined by the calling program as a C-function and then cast to an instance of class function

void setOptClass (MyOpt & *opt*)

Choose user defined optimization class.
Parameters

in	*opt*	Reference to inherited user specified optimization class

void setLowerBound (size_t *i*, real_t *lb*)

Define lower bound for a particular optimization variable.
Method to impose a lower bound for a component of the optimization variable
Parameters

in	*i*	Index of component to bound (index starts from 1)
in	*lb*	Lower bound

void setUpperBound (size_t *i*, real_t *ub*)

Define upper bound for a particular optimization variable.
Method to impose an upper bound for a component of the optimization variable
Parameters

in	*i*	Index of component to bound (index starts from 1)
in	*ub*	Upper bound

void setEqBound (size_t *i*, real_t *b*)

Define value to impose to a particular optimization variable.
Method to impose a value for a component of the optimization variable
Parameters

in	*i*	Index of component to enforce (index starts from 1)
in	*b*	Value to impose

void setUpperBound (real_t *ub*)

Define upper bound for optimization variable.
Case of a one-variable problem
Parameters

in	*ub*	Upper bound

void setUpperBounds (Vect< real_t > & *ub*)

Define upper bounds for optimization variables.
Parameters

in	*ub*	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	*lb*	Lower value

void setLowerBounds (Vect< real_t > & *lb*)

Define lower bounds for optimization variables.
Parameters

in	*lb*	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	*rt*	The temperature reduction factor. The value suggested by Corana et al. is .85. See Goffe et al. for more advice.
in	*ns*	Number of cycles. After *ns∗nb_var* function evaluations, each element of *vm* is adjusted so that approximately half of all function evaluations are accepted. The suggested value is 20.
in	*nt*	Number of iterations before temperature reduction. After *nt∗ns∗n* function evaluations, temperature (t) is changed by the factor *rt*. Value suggested by Corana et al. is *max(100,5∗nb_var)*. See Goffe et al. for further advice.
in	*neps*	Number of final function values used to decide upon termination. See `eps`. Suggested value is *4*
in	*maxevl*	The maximum number of function evaluations. If it is exceeded, the return *code=1*.
in	*t*	The initial temperature. See Goffe et al. for advice.
in	*vm*	The step length vector. On input it should encompass the region of interest given the starting value *x*. For point x[i], the next trial point is selected is from *x*[i]-vm[i] to *x*[i]+vm[i]. Since *vm* 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, *OptimSA* adjusts *vm* to the correct value).
out	*xopt*	optimal values of optimization variables
out	*fopt*	Optimal value of objective

void setTolerance (real_t *toler*)

Set error tolerance.
Parameters

in	*toler*	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, user the function run with arguments

int run (real_t *toler*, int *max_it*)

Run the optimization algorithm.

Parameters

in	*toler*	Tolerance value for convergence testing
in	*max_it*	Maximal number of iterations to achieve convergence

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 beed 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)

  Constructor to partition a mesh into submeshes.
- Partition (Mesh &mesh, int n, vector< int > &epart)

  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 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`

Author

Rachid Touzani

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7.86.2 Constructor & Destructor Documentation

Partition (Mesh & ***mesh,*** **size_t** ***n*** **)**

Constructor to partition a mesh into submeshes.

Parameters

in	*mesh*	Mesh instance
in	*n*	Number of submeshes

Partition (Mesh & *mesh*, int *n*, vector< int > & *epart*)

Constructor using already created submeshes.
Parameters

in	*mesh*	Mesh instance
in	*n*	Number of submeshes
in	*epart*	Vector containing for each element its submesh label (Running from 0 to `n-1`

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	*sm*	Label of submesh
in	*label*	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	*sm*	Label of submesh
in	*label*	Node 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	*sm*	Submesh index
in	*i*	Side label

Returns

Index of submesh

Mesh& getSubMesh (size_t *i*) const

Return reference to submesh.
Parameters

in	*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	*sm*	Index of submesh
in	*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	*sm*	Label of submesh
in	*i*	Side label

int getNbConnectInSubMesh (int *n*, int *s*) const

Get number of connected nodes in a submesh.
Parameters

in	*n*	Label of node for which connections are counted
in	*s*	Label of submesh (starting from 0)

int getNbConnectOutSubMesh (int *n*, int *s*) const

Get number of connected nodes out of a submesh.
Parameters

in	*n*	Label of node for which connections are counted
in	*s*	Label of submesh (starting from 0)

void put (size_t *n*, string *file*) const

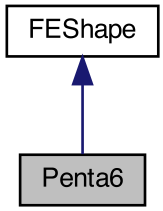
Save a submesh in file.
Parameters

in	*n*	Label of submesh
in	*file*	Name of file in which submesh is saved

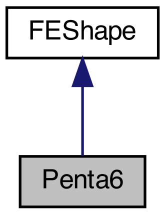
7.87 Penta6 Class Reference

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:



Collaboration 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.
- vector< Point< real_t > > DSh () const

  Return partial derivatives of shape functions of element nodes.
- real_t getMaxEdgeLength () const

  Return Maximum length of pentahedron edges.
- real_t getMinEdgeLength () const

  Return Mimimum length of pentahedron edges.

7.87.1 Detailed Description

Defines a 6-node pentahedral finite element using `P1` interpolation in local coordinates `(s.x,s.y)` and `Q1` 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 `el` are given.

Parameters

in	*element*	Pointer to Element

7.87.3 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.

vector<Point<real_t> > DSh ( ) const

Return partial derivatives of shape functions of element nodes.

Returns

LocalVect instance of partial derivatives of shape functions *e.g.* `dsh(i)`.x, `dsh(i)`.y, are partial derivatives of the *i*-th shape function.

Note

The local point at which the derivatives are computed must be chosen before by using the member function setLocal

7.88 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.

7.88.1 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)

7.88.2 Member Function Documentation

int E2T (real_t & *H*, real_t & *T*, real_t & *gamma*)

Calculate temperature from enthalpy.

This member function is to be called in any equation class that needs phase change laws.

Parameters

`in`	*H*	Enthalpy value
`out`	*T*	Calculated temperature value
`out`	*gamma*	Maximal slope of the curve `H -> 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 -> T`

7.89 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 `!=`
- real_t NNorm () const

  Return squared euclidean norm of vector.
- real_t Norm () const

  Return norm (length) of vector.
- void Normalize ()

  Normalize vector.
- Point< real_t > Director (const Point< real_t > &p) const

  Return Director (Normalized vector)
- bool isCloseTo (const Point< real_t > &a, real_t 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.

7.89.1 Detailed Description

template<class T_>class OFELI::Point< T_ >

Defines a point with arbitrary type coordinates.
Operators = and `()` are overloaded.
Template Parameters

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

Author

Rachid Touzani

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7.89.2 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`

7.89.3 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< real_t > & *a*, real_t *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

7.90 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.

7.90.1 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

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7.90.2 Constructor & Destructor Documentation

Point2D (T_ *a*, T_ *b* = *T_(0)*)

Constructor that assigns `a`, `b` to `x`-, `y`- and `y`-coordinates respectively.
Default value for *b* is 0

7.90.3 Member Function Documentation

T_& operator() (size_t *i*)

Operator() : Non constant version.
Values `i = 1,2` correspond to `x` and `y` respectively

const T_& operator() (size_t *i*) const

Operator() : Constant version.
Values `i=1,2` correspond to `x` and `y` respectively

T_& operator[ ] (size_t *i*)

Operator `[]`: Non constant version.
Values `i=0,1` correspond to `x` and `y` respectively

const T_& operator[ ] (size_t *i*) const

Operator `[]` Constant version.
Values `i=0,1` correspond to `x` and `y` respectively

Point2D<T_>& operator= (const Point2D< T_ > & *p*)

Operator =
Assign point `p` to current instance

Point2D<T_>& operator+= (const Point2D< T_ > & *p*)

Operator +=
Add point `p` to current instance

Point2D<T_>& operator-= (const Point2D< T_ > & *p*)

Operator `-=`
Subtract point `p` from current instance

Point2D<T_>& operator= (const T_ & *a*)

Operator =
Assign constant `a` to current instance coordinates

Point2D<T_>& operator+= (const T_ & *a*)

Operator +=
Add constant `a` to current instance coordinates

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

Operator `-=`
Subtract constant `a` from current instance coordinates

Point2D<T_>& operator∗= (const T_ & *a*)

Operator ∗=
Multiply constant `a` by current instance coordinates

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

Operator /=
Divide current instance coordinates by `a`

bool operator== (const Point2D< T_ > & *p*)

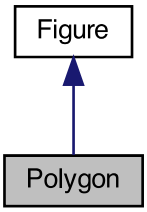
Operator ==
Return `true` if current instance is equal to `p`, `false` otherwise.

bool operator!= (const Point2D< T_ > & *p*)

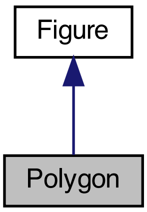
Operator `!=`
Return `false` if current instance is equal to `p`, `true` otherwise.

7.91 Polygon Class Reference

To store and treat a polygonal figure.
Inheritance diagram for Polygon:



Collaboration 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 ∗=.

7.91.1 Detailed Description

To store and treat a polygonal figure.

7.91.2 Constructor & Destructor Documentation

Polygon (const Vect< Point< real_t > > & *v*, int *code* = *1*)

Constructor.
Parameters

in	*v*	Vect instance containing list of coordinates of polygon vertices
in	*code*	Code to assign to the generated domain (Default value = 1)

7.91.3 Member Function Documentation

void setVertices (const Vect< Point< real_t > > & *v*)

Assign vertices of polygon.
Parameters

in	*v*	Vector containing vertices coordinates in counter clockwise order

real_t getSignedDistance (const Point< real_t > & *p*) const `[virtual]`

Return signed distance of a given point from the current polygon.
The computed distance is negative if `p` lies in the polygon, negative if it is outside, and 0 on its boundary
Parameters

in	*p*	Point<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`

7.92 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.

7.92.1 Detailed Description

template<class T_>class OFELI::Prec< T_ >

To set a preconditioner.

The preconditioner type is chosen in the constructor

Template Parameters

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

Author

Rachid Touzani

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7.92.2 Constructor & Destructor Documentation

Prec (int *type*)

Constructor that chooses preconditioner.

Parameters

in	*type*	Preconditioner type: • `IDENT_PREC`: Identity preconditioner (No preconditioning) • `DIAG_PREC`: Diagonal preconditioner • `DILU_PREC`: Diagonal Incomplete factorization preconditioner • `ILU_PREC`: Incomplete factorization preconditioner • `SSOR_PREC`: SSOR (Symmetric Successive Over Relaxation) preconditioner

Prec (const SpMatrix< T_ > & *A*, int *type* = DIAG_PREC)

Constructor using matrix of the linear system to precondition.
Parameters

in	*A*	Matrix to precondition
in	*type*	Preconditioner type: • `IDENT_PREC`: Identity preconditioner (No preconditioning) • `DIAG_PREC`: Diagonal preconditioner • `DILU_PREC`: Diagonal Incomplete factorization preconditioner • `ILU_PREC`: Incomplete factorization preconditioner • `SSOR_PREC`: SSOR (Symmetric Successive Over Relaxation) preconditioner

Prec (const Matrix< T_ > * *A*, int *type* = DIAG_PREC)

Constructor using matrix of the linear system to precondition.
Parameters

in	*A*	Pointer to abstract Matrix class to precondition
in	*type*	Preconditioner type: • `IDENT_PREC`: Identity preconditioner (No preconditioning) • `DIAG_PREC`: Diagonal preconditioner • `DILU_PREC`: Diagonal Incomplete factorization preconditioner • `ILU_PREC`: Incomplete factorization preconditioner • `SSOR_PREC`: SSOR (Symmetric Successive Over Relaxation) preconditioner

7.92.3 Member Function Documentation

void setType (int *type*)

Define preconditioner type.

Parameters

in	*type*	Preconditioner type: • `IDENT_PREC`: Identity preconditioner (No preconditioning) • `DIAG_PREC`: Diagonal preconditioner • `DILU_PREC`: Diagonal Incomplete factorization preconditioner • `ILU_PREC`: Incomplete factorization preconditioner • `SSOR_PREC`: SSOR (Symmetric Successive Over Relaxation) preconditioner

void setMatrix (const Matrix< T_ > * *A*)

Define pointer to matrix for preconditioning (if this one is abstract)

Parameters

in	*A*	Matrix to precondition

void setMatrix (const SpMatrix< T_ > & *A*)

Define the matrix for preconditioning.

Parameters

in	*A*	Matrix to precondition (instance of class SpMatrix)

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

7.93 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 std::string &file)

  Constructor that gives an instance of class Mesh and the data file name.
- ~Prescription ()

  Destructor.
- int get (EqDataType type, Vect< real_t > &v, real_t time=0, size_t dof=0)

7.93.1 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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7.93.2 Constructor & Destructor Documentation

Prescription (Mesh & *mesh*, const std::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	*mesh*	Mesh instance
in	*file*	Name of Prescription file

7.93.3 Member Function Documentation

int get (EqDataType *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

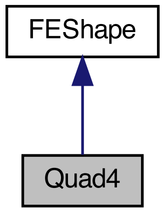
in	*type*	Type of data to seek. To choose among the enumerated values: • `BOUNDARY_CONDITION`: Read values for (Dirichlet) boundary conditions • `BOUNDARY_FORCE`: Read values for boundary force (Neumann boundary condition). The values `TRACTION` and `FLUX` have the same effect. • `BODY_FORCE`: Read values for body (or volume) forces. The value `SOURCE` has the same effect. • `POINT_FORCE`: Read values for pointwise forces • `CONTACT_DISTANCE`: Read values for contact distance (for contact mechanics) • `INITIAL_FIELD`: Read values for initial solution • `SOLUTION`: Read values for a solution vector

`in,out`	*v*	Vect instance that is instantiated on input and filled on output
`in`	*time*	Value of time for which data is read [Default: `0`].
`in`	*dof*	DOF to store (Default is `0`: All DOFs are chosen).

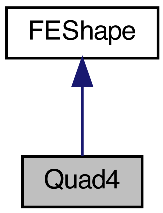
7.94 Quad4 Class Reference

Defines a 4-node quadrilateral finite element using `Q`$_1$ isoparametric interpolation.

Inheritance diagram for Quad4:



Collaboration diagram for Quad4:



Public Member Functions

- Quad4 ()

  Default Constructor.
- Quad4 (const Element ∗element)

  Constructor when data of Element `el` *are given.*
- Quad4 (const Side ∗side)

  Constructor when data of Side `sd` *are given.*
- ∼Quad4 ()

  Destructor.

- void set (const Element *el)

  Choose element by giving its pointer.
- void set (const Side *sd)

  Choose side by giving its pointer.
- void setLocal (const Point< real_t > &s)

  Initialize local point coordinates in element.
- void atGauss (int n, std::vector< real_t > &sh, std::vector< Point< real_t > > &dsh, std::vector< real_t > &w)

  Calculate shape functions and their partial derivatives and integration weights.
- 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.

7.94.1 Detailed Description

Defines a 4-node quadrilateral finite element using `Q1` isoparametric interpolation.

The reference element is the square `[-1,1]x[-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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7.94.2 Constructor & Destructor Documentation

Quad4 (const Element * *element*)

Constructor when data of Element `el` are given.

Parameters

in	*element*	Pointer to Element

Quad4 (const Side * *side*)

Constructor when data of Side `sd` are given.

Parameters

in	*side*	Pointer to Side

7.94.3 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.

void atGauss (int *n*, std::vector< real_t > & *sh*, std::vector< Point< real_t > > & *dsh*, std::vector< real_t > & *w*)

Calculate shape functions and their partial derivatives and integration weights.
Parameters

in	*n*	Number of Gauss-Legendre integration points in each direction
in	*sh*	Vector of shape functions at Gauss points
in	*dsh*	Vector of shape function derivatives at Gauss points
in	*w*	Weights of integration formula at Gauss points

Point<real_t> Grad (const LocalVect< real_t, 4 > & *u*, const Point< real_t > & *s*)

Return gradient of a function defined at element nodes.
Parameters

in	*u*	Vector of values at nodes
in	*s*	Local coordinates (in `[-1,1]*[-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

7.95 Reconstruction Class Reference

To perform various reconstruction operations.

Public Member Functions

- Reconstruction ()
  Default constructor.
- Reconstruction (const Mesh &ms)
  Constructor using a refrence to a Mesh instance.
- ~Reconstruction ()
  Destructor.
- void setMesh (const 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_1) field by L^2 projection.

7.95.1 Detailed Description

To perform various reconstruction operations.

This class enables various reconstruction operations like smoothing, projections, ...

Author

Rachid Touzani

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7.95.2 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	u	Vect instance that contains field to smooth
out	v	Vect 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_1) field by L^2 projection.

Parameters

in	u	Vect instance that contains field to smooth
out	v	Vect instance that contains on output smoothed field

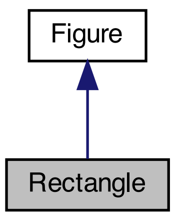
Warning

This function is valid for P_1 triangles (2-D) only.

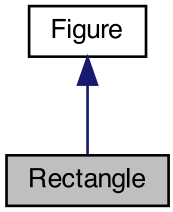
7.96 Rectangle Class Reference

To store and treat a rectangular figure.

Inheritance diagram for Rectangle:



Collaboration 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 ∗=.

7.96.1 Detailed Description

To store and treat a rectangular figure.

7.96.2 Constructor & Destructor Documentation

Rectangle (const Point< real_t > & ***bbm*****, const Point< real_t > &** ***bbM*****, int** ***code*** **=** *1* **)**

Constructor.
Parameters

in	*bbm*	Left Bottom point of rectangle
in	*bbM*	Right Top point of rectangle
in	*code*	Code to assign to rectangle

7.96.3 Member Function Documentation

void setBoundingBox (const Point< real_t > & *bbm*, const Point< real_t > & *bbM*)

Assign bounding box of the rectangle.
Parameters

in	*bbm*	Left Bottom point
in	*bbM*	Right Top point

real_t getSignedDistance (const Point< real_t > & *p*) const `[virtual]`

Return signed distance of a given point from the current rectangle.
The computed distance is negative if `p` lies in the rectangle, negative if it is outside, and `0` on its boundary
Parameters

in	*p*	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`

7.97 Side Class Reference

To store and treat finite element sides (edges in 2-D or faces in 3-D)

Public Types

- enum SideType {
  INTERNAL_SIDE = 0,
  EXTERNAL_BOUNDARY = 1,
  INTERNAL_BOUNDARY = 2 }

Public Member Functions

- Side ()
  Default Constructor.
- Side (size_t label, const string &shape)
  Constructor initializing side label and shape.
- Side (size_t label, int shape)

Constructor initializing side label and shape.
- Side (const Side &sd)

  Copy constructor.
- ∼Side ()

  Destructor.
- void Add (Node ∗node)

  Insert a node at end of list of nodes of side.
- void Add (Edge ∗edge)

  Insert an edge at end of list of edges of side.
- void setLabel (size_t i)

  Define label of side.
- void setFirstDOF (size_t n)

  Define First DOF.
- void setNbDOF (size_t nb_dof)

  Set number of degrees of freedom (DOF).
- void DOF (size_t i, size_t dof)

  Define label of DOF.
- void setDOF (size_t &first_dof, size_t nb_dof)

  Define number of DOF.
- void setCode (size_t dof, int code)

  Assign code to a DOF.
- void 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.

- Point< real_t > getCenter () const

  Return coordinates of center 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.

7.97.1 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:

Shape Shape name Dimension Min. number of nodes Line line 3 2 Triangle tria 3 3 Quadrilateral quad 3 4

Author

Rachid Touzani

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7.97.2 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

7.97.3 Constructor & Destructor Documentation

Side (size_t *label*, const string & *shape*)

Constructor initializing side label and shape.

Parameters

in	*label*	Label to assign to side.
in	*shape*	Shape of side (See class description).

Side (size_t *label*, int *shape*)

Constructor initializing side label and shape.

Parameters

in	*label*	to assign to side.
in	*shape*	of side (See enum ElementShape in Mesh).

7.97.4 Member Function Documentation

void DOF (size_t *i*, size_t *dof*)

Define label of DOF.

Parameters

in	*i*	DOF index
in	*dof*	Its label

void setDOF (size_t & *first_dof*, size_t *nb_dof*)

Define number of DOF.
Parameters

in,out	*first_dof*	Label of the first DOF in input that is actualized
in	*nb_dof*	Number of DOF

void setCode (size_t *dof*, int *code*)

Assign code to a DOF.
Parameters

in	*dof*	DOF to which code is assigned
in	*code*	Code to assign

void Add (Element ∗ *el*)

Set pointer to neighbor element.
Parameters

in	*el*	Pointer to element to add as a neigbor 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	*el*	Pointer to element to set as a neighbor element
in	*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	*dof*	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*	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	*el*	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 get←UnitNormal.

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::get←BoundarySides()** 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

7.98 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)

7.98.1 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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7.98.2 Member Function Documentation

void selectCode (int *code*, int *dof* = *1*)

Select sides having a given code for a given degree of freedom.

Parameters

`in`	*code*	Code that sides share
`in`	*dof*	Degree of Freedom label [Default: 1]

void unselectCode (int *code*, int *dof* = *1*)

Unselect sides having a given code for a given degree of freedom.

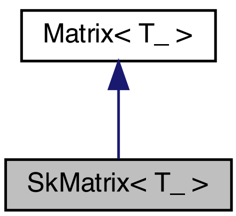
Parameters

`in`	*code*	Code of sides to exclude
`in`	*dof*	Degree of Freedom label [Default: 1]

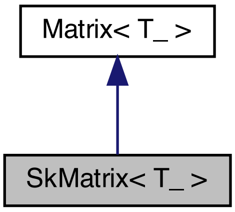
7.99 SkMatrix< T_ > Class Template Reference

To handle square matrices in skyline storage format.

Inheritance diagram for SkMatrix< T_ >:



Collaboration 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 ofthe 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 ofthe 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, bool fact=true)

  Solve linear system.
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)

  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.

7.99.1 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

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7.99.2 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`	*mesh*	Mesh 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.
`in`	*is_diagonal*	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	*ColHt*	Vect instance that contains rows lengths of matrix.

7.99.3 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	*mesh*	Mesh 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 setSkyline (Mesh & *mesh*)

Determine matrix structure.

This member function calculates matrix structure using a Mesh instance.

Parameters

in	*mesh*	Mesh 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*	Index of the DOF

void set (size_t *i*, size_t *j*, const T_ & *val*) `[virtual]`

Assign a value to an entry ofthe matrix.

Parameters

in	*i*	Row index (starting at `i=1`)
in	*j*	Column index (starting at `i=1`)
in	*val*	Value to assign to entry `a(i,j)`

Implements Matrix< T_ >.

void Axpy (T_ *a*, const SkMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.

Parameters

in	a	Scalar to premultiply
in	m	Matrix by which a is multiplied. The result is added to current instance

void Axpy (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_ >.

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
in,out	y	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	x	Vector to multiply by matrix
in,out	y	Vector to add to the result. y contains on output the result.

void MultAdd (T_ *a*, const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply matrix by a vector and add to another one.

Parameters

in	a	Constant to multiply by matrix
in	x	Vector to multiply by matrix
in,out	y	Vector to add to the result. y contains on output the result.

Implements Matrix< T_ >.

void Mult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply matrix by vector x and save in y.

Parameters

in	x	Vector to multiply by matrix
out	y	Vector that contains on output the result.

Implements Matrix< T_ >.

void TMult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply transpose of matrix by vector x and save in y.

Parameters

in	*x*	Vector to multiply by matrix
out	*y*	Vector that contains on output the result.

Implements Matrix< T_ >.

void add (size_t *i*, size_t *j*, const T_ & *val*) [virtual]

Add a constant value to an entry ofthe matrix.
Parameters

in	*i*	Row index
in	*j*	Column index
in	*val*	Constant value to add to `a(i,j)`

Implements Matrix< T_ >.

size_t getColHeight (size_t *i*) const

Return column height.
Column height at entry `i` is returned.

T_ operator() (size_t *i*, size_t *j*) const [virtual]

Operator () (Constant version).
Parameters

in	*i*	Row index
in	*j*	Column index

Implements Matrix< T_ >.

T_& operator() (size_t *i*, size_t *j*) [virtual]

Operator () (Non constant version).
Parameters

in	*i*	Row index
in	*j*	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	*mesh*	Mesh instance from which information is extracted.
in	*b*	Vect instance that contains right-hand side.
in	*u*	Vect instance that conatins imposed valued at DOFs where they are to be imposed.

in	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

void 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	*b*	Vect instance that contains right-hand side.
in	*u*	Vect instance that conatins imposed valued at DOFs where they are to be imposed.
in	*flag*	Parameter to determine whether only the right-hand side is to be modified (`dof`>0) or both matrix and right-hand side (`dof=0`, default value).

SkMatrix<T_>& operator= (const SkMatrix< T_ > & *m*)

Operator =.

Copy matrix `m` to current matrix instance.

SkMatrix<T_>& operator= (const T_ & *x*)

Operator =.

define the matrix as a diagonal one with all diagonal entries equal to `x`.

SkMatrix<T_>& operator+= (const SkMatrix< T_ > & *m*)

Operator +=.

Add matrix `m` to current matrix instance.

SkMatrix<T_>& operator+= (const T_ & *x*)

Operator +=.

Add constant value `x` to matrix entries.

SkMatrix<T_>& operator*= (const T_ & *x*)

Operator *=.

Premultiply matrix entries by constant value `x`.

int setLU ( )

Factorize the matrix (LU factorization)

LU factorization of the matrix is realized. Note that since this is an in place factorization, the contents of the matrix are modified.

Returns

- `0` if factorization was normally performed,
- `n` if the `n`-th pivot is null.

Remarks

A flag in this class indicates after factorization that this one has been realized, so that, if the member function solve is called after this no further factorization is done.

int solve (Vect< T_ > & *b*, bool *fact* = `true`) `[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`	*b*	Vect instance that contains right-hand side on input and solution on output.
`in`	*fact*	Set true if matrix is to be factorized (Default value), false if not

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*, bool *fact* = `true`) `[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`	*b*	Vect instance that contains right-hand side.
`out`	*x*	Vect instance that contains solution
`in`	*fact*	Set true if matrix is to be factorized (Default value), false if not

Returns

- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

Implements Matrix< T_ >.

T_* get ( ) const

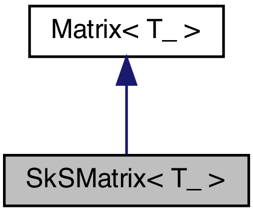
Return C-Array.

Skyline of matrix is stored row by row.

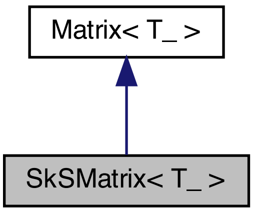
7.100 SkSMatrix< T_ > Class Template Reference

To handle symmetric matrices in skyline storage format.

Inheritance diagram for SkSMatrix< T_ >:



Collaboration 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 ofthe 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, bool fact=true)

  Solve linear system.
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=true)

  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.*

7.100.1 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

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7.100.2 Constructor & Destructor Documentation

SkSMatrix ( )

Default constructor.

Initializes a zero-dimension matrix

SkSMatrix (size_t *size*, int *is_diagonal* = `false`)

Constructor that initializes a dense symmetric matrix.

Normally, for a dense matrix this is not the right class.

Parameters

in	*size*	Number of matrix rows (and columns).
in	*is_diagonal*	Boolean to select if the matrix is diagonal or not [Default: false]

SkSMatrix (Mesh & *mesh*, size_t *dof* = 0, int *is_diagonal* = false)

Constructor using mesh to initialize skyline structure of matrix.
Parameters

in	*mesh*	Mesh 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.
in	*is_diagonal*	Boolean argument to say is the matrix is actually a diagonal matrix or not.

SkSMatrix (const Vect< size_t > & *ColHt*)

Constructor that initializes skyline structure of matrix using vector of column height.
Parameters

in	*ColHt*	Vect instance that contains rows lengths of matrix.

SkSMatrix (const Vect< size_t > & *I*, const Vect< size_t > & *J*, int *opt* = 1)

Constructor for a square matrix using non zero row and column indices.
Parameters

in	*I*	Vector containing row indices
in	*J*	Vector containing column indices
in	*opt*	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*	Vector containing row indices
in	*J*	Vector containing column indices
in	*a*	Vector containing matrix entries in the same order than the one given by `I` and `J`
in	*opt*	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

7.100.3 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	*mesh*	Mesh 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 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 ofthe matrix.

Parameters

in	*i*	Row index
in	*j*	Column index
in	*val*	Value to assign to `a(i,j)`

Implements Matrix< T_ >.

void Axpy (T_ *a*, const SkSMatrix< T_ > & *m*)

Add to matrix the product of a matrix by a scalar.

Parameters

in	*a*	Scalar to premultiply
in	*m*	Matrix by which `a` is multiplied. The result is added to current instance

void Axpy (T_ *a*, const Matrix< T_ > * *m*) [virtual]

Add to matrix the product of a matrix by a scalar.

Parameters

in	*a*	Scalar to premultiply
in	*m*	Pointer to 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	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 MultAdd (T_ *a*, const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply matrix by vector `a*x` and add to `y`.

Parameters

in	a	Constant to multiply by matrix
in	x	Vector to multiply by matrix
in,out	y	Vector to add to the result. y contains on output the result.

Implements Matrix< T_ >.

void Mult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply matrix by vector `x` and save in `y`

Parameters

in	x	Vector to multiply by matrix
out	y	Vector that contains on output the result.

Implements Matrix< T_ >.

void TMult (const Vect< T_ > & *x*, Vect< T_ > & *y*) const `[virtual]`

Multiply transpose of matrix by vector x and save in y.

Parameters

in	x	Vector to multiply by matrix
out	y	Vector that contains on output the result.

Implements Matrix< T_ >.

void add (size_t *i*, size_t *j*, const T_ & *val*) `[virtual]`

Add a constant to an entry of the matrix.

Parameters

in	i	Row index
in	j	Column index
in	val	Constant value to add to `a(i,j)`

Implements Matrix< T_ >.

size_t getColHeight (size_t *i*) const

Return column height.

Column height at entry `i` is returned.

T_& operator() (size_t *i*, size_t *j*) `[virtual]`

Operator () (Non constant version).

Parameters

in	*i*	Row index
in	*j*	Column index

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*	Row index
in	*j*	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*	Vect instance that contains right-hand side
out	*x*	Vect instance that contains solution

Returns

- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null

Solution is performed only is factorization has previously been invoked.

int solve (Vect< T_ > & *b*, bool *fact* = *true*) `[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 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 setLDLt realizes the factorization step only.

Parameters

in,out	*b*	Vect instance that contains right-hand side on input and solution on output.
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

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*, bool *fact* = *true*) `[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 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 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*	Vect instance that contains right-hand side.
out	*x*	Vect instance that contains solution
in	*fact*	Set true if matrix is to be factorized (Default value), false if not

Returns

- `0` if solution was normally performed,
- `n` if the `n`-th pivot is null.

Implements Matrix< T_ >.

T_* get ( ) const

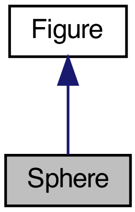
Return C-Array.

Skyline of matrix is stored row by row.

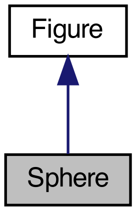
7.101 Sphere Class Reference

To store and treat a sphere.

Inheritance diagram for Sphere:



Collaboration diagram for Sphere:



Public Member Functions

- Sphere ()

  Default construcor.
- 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 *=.*

7.101.1 Detailed Description

To store and treat a sphere.

7.101.2 Constructor & Destructor Documentation

Sphere (const Point< real_t > & *c*, real_t *r*, int *code* = *1*)

Constructor.
Parameters

in	*c*	Coordinates of center of sphere
in	*r*	Radius
in	*code*	Code to assign to the generated sphere [Default: 1]

7.101.3 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	*p*	Point<double> instance

Reimplemented from Figure.

Sphere& operator+= (Point< real_t > *a*)

Operator +=.
Translate sphere by a vector `a`

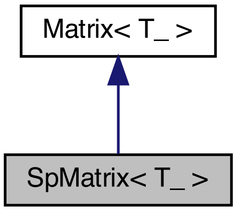
Sphere& operator+= (real_t *a*)

Operator *=.
Scale sphere by a factor `a`

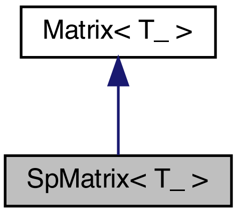
7.102 SpMatrix< T_ > Class Template Reference

To handle matrices in sparse storage format.

Inheritance diagram for SpMatrix< T_ >:



Collaboration 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 Vect< RC > &I, int opt=1)

  Constructor for a square matrix using non zero row and column indices.
- SpMatrix (const Vect< RC > &I, const Vect< T_ > &a, int opt=1)

  Constructor for a square matrix using non zero row and column indices.

- SpMatrix (size_t nr, size_t nc, const vector< size_t > &row_ptr, const vector< size_t > &col↩
_ind)

  Constructor for a rectangle matrix.
- SpMatrix (size_t nr, size_t nc, const vector< size_t > &row_ptr, const vector< size_t > &col↩
ind, const vector< T > &a)

  Constructor for a rectangle matrix.
- SpMatrix (const vector< size_t > &row_ptr, const vector< size_t > &col_ind)

  Constructor for a rectangle matrix.
- SpMatrix (const vector< size_t > &row_ptr, const vector< size_t > &col_ind, const vector< T_ > &a)

  Constructor for a rectangle matrix.
- SpMatrix (const SpMatrix &m)

  Copy constructor.
- ~SpMatrix ()

  Destructor.
- void Identity ()

  Define matrix as identity.
- void Dense ()

  Define matrix as a dense one.
- 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)
- T_ operator() (size_t i) const

  Operator () with one argument (Constant version)
- 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 $a*x$ and add to y.
- void TMult (const Vect< T_ > &x, Vect< T_ > &y) const

  Multiply transpose of matrix by vector x and save in y.
- void Axpy (T_ a, const SpMatrix< 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 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, bool fact=false)

  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.

Friends

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

7.102.1 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

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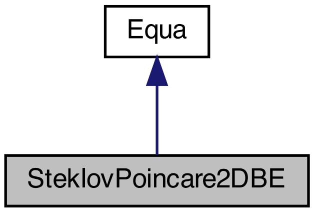
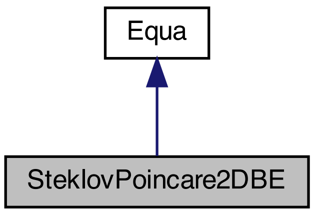
7.103 SteklovPoincare2DBE Class Reference

Solver of the Steklov Poincare problem in 2-D geometries using piecewie constant boundary elemen.

Inheritance diagram for SteklovPoincare2DBE:



Collaboration diagram for SteklovPoincare2DBE:



Public Member Functions

- SteklovPoincare2DBE ()

  Default Constructor.
- SteklovPoincare2DBE (Mesh &ms)

  Constructor using mesh data.
- SteklovPoincare2DBE (Mesh &ms, Vect< real_t > &u)

  Constructor that solves the Steklov Poincare problem.
- ~SteklovPoincare2DBE ()

  Destructor.
- void setMesh (Mesh &ms)

  set Mesh instance
- void setExterior ()

  Choose domain of the Laplace equation as exterior one.
- int run ()

  Solve Setklov-Poincare problem.

7.103.1 Detailed Description

Solver of the Steklov Poincare problem in 2-D geometries using piecewie 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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7.103.2 Constructor & Destructor Documentation

SteklovPoincare2DBE (Mesh & *ms*)

Constructor using mesh data.

Parameters

in	*ms*	Reference to Mesh instance.

SteklovPoincare2DBE (Mesh & *ms*, Vect< real_t > & *u*)

Constructor that solves the Steklov Poincare problem.

This constructor calls member function setMesh and Solve.

Parameters

in	*ms*	Reference to mesh instance.
in	*u*	Reference to solution vector. It contains the solution (normal derivative on boundary, once problem is solved

7.103.3 Member Function Documentation

void setMesh (Mesh & *ms*)

set Mesh instance

Parameters

in	*ms*	Mesh instance

void setExterior ( )

Choose domain of the Laplace equation as exterior one.

By default the domain where the Laplace equation is considered is the interior domain, *i.e.* bounded. This function chooses the exterior of a bounded domain

int run ( )

Solve Setklov-Poincare problem.

This member function builds and solves the Steklov-Poincare equation.

7.104 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 x)

  Return the calculated value of the function.
- real_t getDerivative (string funct, real_t x)

  Return the derivative of the function at a given point.
- real_t getValue (string funct, real_t x, real_t y)

  Return the calculated value of the function.
- real_t getValue (string funct, real_t x, real_t y, real_t z)

  Return the calculated value of the function.
- real_t getValue (string funct, real_t x, real_t y, real_t z, real_t t)

  Return the calculated value of the function.
- size_t getNbFuncts () const

  Get the Number of read functions.
- size_t getNbVar (size_t n) const

  Get number of variables of a given function.
- string getFunctName (size_t n) const

  Get the name of a read function.
- size_t getSize (size_t n, size_t i) const

  Get number of points defining tabulation.
- real_t getMinVar (size_t n, size_t i) const

  Get minimal value of a variable.
- real_t getMaxVar (size_t n, size_t i) const

  Get maximal value of a variable.

7.104.1 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". The abcissae are uniformly distributed.

Author

Rachid Touzani

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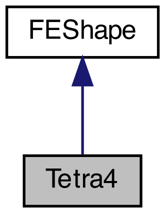
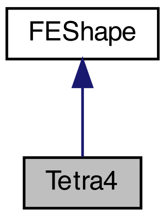
7.105 Tetra4 Class Reference

Defines a three-dimensional 4-node tetrahedral finite element using P_1 interpolation.

Inheritance diagram for Tetra4:



Collaboration 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`.
- 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.
- std::vector< Point< real_t > > DSh () const
  Calculate partial derivatives of shape functions at element nodes.

7.105.1 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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7.105.2 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> 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`

std::vector<Point<real_t> > DSh ( ) const

Calculate partial derivatives of shape functions at element nodes.

Returns

Vector of partial derivatives of shape functions *e.g.* `dsh`[i-1].x, `dsh`[i-1].y, are partial derivatives of the *i*-th shape function

7.106 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)

7.106.1 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

Rachid Touzani

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7.106.2 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

7.107 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 (Equa &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 setRHS (string exp)

  Set right-hand side as defined by a regular expression.
- void setBC (Vect< real_t > &u)

  Set vector containing boundary condition to enforce.
- void setBC (int code, string exp)

  Set boundary condition as defined by a regular expression.
- 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.
- 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=nullptr)

  Assemble element arrays into global matrix and right-hand side.
- void SAssembly (const Side &sd, real_t *b, real_t *A=nullptr)

  Assemble side arrays into global matrix and right-hand side.
- LinearSolver< real_t > & getLSolver ()

  Return LinearSolver instance.

7.107.1 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*)

7.107.2 Constructor & Destructor Documentation

TimeStepping (TimeScheme *s*, real_t *time_step* = theTimeStep, real_t *final_time* = theFinalTime)

Constructor using time discretization data.
Parameters

in	*s*	Choice of the scheme: To be chosen in the enumerated variable *TimeScheme* (see the presentation of the class)
in	*time_step*	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	*final_time*	Value of the final time (time starts at 0). The default value for this parameter is the value given by the global variable `theFinalTime`

7.107.3 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	*s*	Choice of the scheme: To be chosen in the enumerated variable *TimeScheme* (see the presentation of the class)
in	*time_step*	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	*final_time*	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 setLinearSolver (LinearSolver< real_t > & *ls*)

Set reference to LinearSolver instance.
Parameters

in	*ls*	Reference to LinearSolver instance

void setPDE (Equa & *eq*, bool *nl* = `false`)

Define partial differential equation to solve.

The used equation class must have been constructed using the Mesh instance

Parameters

in	*eq*	Reference to equation instance
in	*nl*	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	*f*	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	*f*	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 somtimes 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 setRHS (string *exp*)

Set right-hand side as defined by a regular expression.
Parameters

in	*exp*	Regular expression as a function of `x`, `y`, `z` and `t`

void setBC (int *code*, string *exp*)

Set boundary condition as defined by a regular expression.
Parameters

in	*code*	Code for which expression is assigned
in	*exp*	Regular expression to assign as a function of `x`, `y`, `z` and `t`

void setNewmarkParameters (real_t *beta*, real_t *gamma*)

Define parameters for the Newmark scheme.
Parameters

in	*beta*	Parameter beta [Default: `0.25`]
in	*gamma*	Parameter gamma [Default: `0.5`]

void setConstantMatrix ( )

Say that matrix problem is constant.
This is useful if the linear system is solved by a factorization method but has no effect otherwise

void setNonConstantMatrix ( )

Say that matrix problem is variable.

This is useful if the linear system is solved by a factorization method but has no effect otherwise

void setLinearSolver (Iteration *s* = DIRECT_SOLVER, Preconditioner *p* = DIAG_PREC)

Set linear solver data.

Parameters

in	*s*	Solver identification parameter. To be chosen in the enumeration variable Iteration: DIRECT_SOLVER, CG_SOLVER, CGS_SOLVER, BICG_SOL←VER, BICG_STAB_SOLVER, GMRES_SOLVER, QMR_SOLVE←R [Default: `DIRECT_SOLVER`]
in	*p*	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	*a0*	Reference to Vect instance defining the 0-th order term
in	*A0*	Reference to Matrix 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	*a0*	Reference to Vect instance defining the 0-th order term
in	*a1*	Reference to Vect instance defining the first order term
in	*a2*	Reference to Vect instance defining the second order term

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`	*opt*	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* = `nullptr`)

Assemble element arrays into global matrix and right-hand side.

This member function is to be called from finite element equation classes

Parameters

`in`	*el*	Reference to Element class
`in`	*b*	Pointer to element right-hand side
`in`	*A0*	Pointer to matrix of 0-th order term (involving no time derivative)
`in`	*A1*	Pointer to matrix of first order term (involving time first derivative)
`in`	*A2*	Pointer to matrix of second order term (involving time second derivative) [Default: `nullptr`]

void SAssembly (const Side & *sd*, real_t * *b*, real_t * *A* = `nullptr`)

Assemble side arrays into global matrix and right-hand side.

This member function is to be called from finite element equation classes

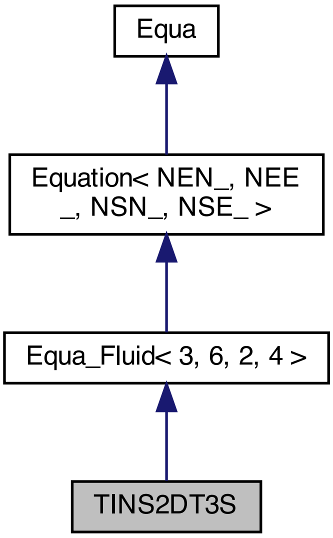
Parameters

`in`	*sd*	Reference to Side class
`in`	*b*	Pointer to side right-hand side
`in`	*A*	Pointer to matrix [Default: `nullptr`]

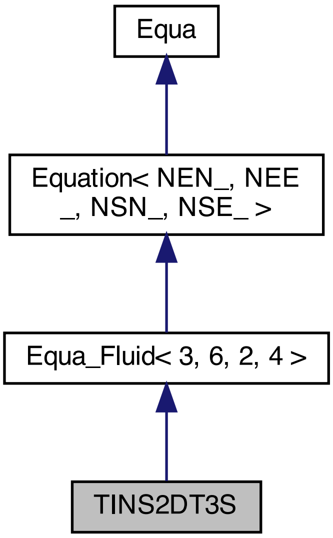
7.108 TINS2DT3S Class Reference

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:



Collaboration diagram for TINS2DT3S:



Public Member Functions

- TINS2DT3S ()
  Default Constructor.
- TINS2DT3S (Mesh &mesh)
  Constructor using mesh.
- TINS2DT3S (Mesh &mesh, Vect< real_t > &u)
  Constructor using mesh and velocity.
- ~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)

7.108.1 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.

Author

Rachid Touzani

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7.108.2 Constructor & Destructor Documentation

TINS2DT3S (Mesh & *mesh*)

Constructor using mesh.

Parameters

in	*mesh*	Mesh instance

TINS2DT3S (Mesh & *mesh*, Vect< real_t > & *u*)

Constructor using mesh and velocity.

Parameters

in	*mesh*	Mesh instance
in,out	*u*	Vect instance containing initial velocity. This vector is updated during computations and will therefore contain velocity at each time step

7.108.3 Member Function Documentation

void setInput (EqDataType *opt*, Vect< real_t > & *u*)

Set equation input data.

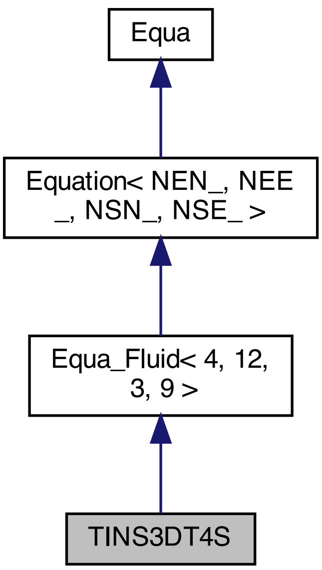
Parameters

in	*opt*	Parameter to select type of input (enumerated values) • `INITIAL_FIELD`: Initial temperature • `BOUNDARY_CONDITION`: Boundary condition (Dirichlet) • `SOURCE`: Body force applied to fluid • `TRACTION`: Heat flux (Neumann boundary condition) • `VELOCITY_FIELD`: Velocity vector (for the convection term)
in	*u*	Vector containing input data (Vect instance)

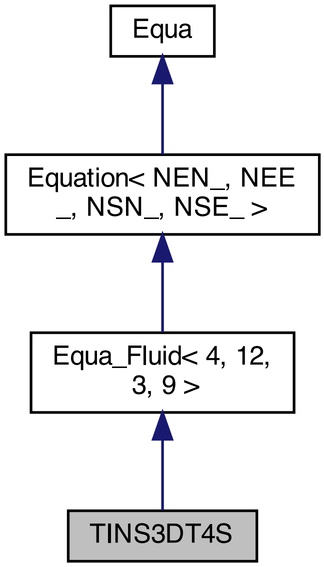
7.109 TINS3DT4S Class Reference

Builds finite element arrays for transient incompressible fluid flow using Navier-Stokes equations in 3-D domains. Numerical approximation uses stabilized 4-node tatrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

Inheritance diagram for TINS3DT4S:



Collaboration diagram for TINS3DT4S:



Public Member Functions

- TINS3DT4S ()

  Default Constructor.
- TINS3DT4S (Mesh &ms)

  Constructor using mesh.
- TINS3DT4S (Mesh &ms, Vect< real_t > &u)

  Constructor using mesh and velocity.
- ~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)

7.109.1 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 tatrahedral finite elements for velocity and pressure. 2nd-order projection scheme is used for time integration.

Author

Rachid Touzani

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7.109.2 Constructor & Destructor Documentation

TINS3DT4S (Mesh & *ms*)

Constructor using mesh.

Parameters

`in`	*ms*	Mesh instance

TINS3DT4S (Mesh & *ms*, Vect< real_t > & *u*)

Constructor using mesh and velocity.

Parameters

`in`	*ms*	Mesh instance
`in,out`	*u*	Vect instance containing initial velocity. This vector is updated during computations and will therefore contain velocity at each time step

7.109.3 Member Function Documentation

void setInput (EqDataType *opt*, Vect< real_t > & *u*)

Set equation input data.

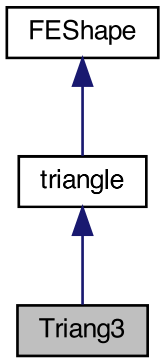
Parameters

`in`	*opt*	Parameter to select type of input (enumerated values) • `INITIAL_FIELD`: Initial temperature • `BOUNDARY_CONDITION_DATA`: Boundary condition (Dirichlet) • `SOURCE_DATA`: Heat source • `FLUX_DATA`: Heat flux (Neumann boundary condition). N↩ OT IMPLEMENTED • `VELOCITY_FIELD`: Velocity vector (for the convection term)

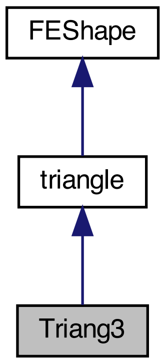
in	u	Vector containing input data (Vect instance)

7.110 Triang3 Class Reference

Defines a 3-Node (P_1) triangle.
Inheritance diagram for Triang3:



Collaboration 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.
- std::vector< Point< real_t > > DSh () const

  Return partial derivatives of shape functions of element nodes.
- 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.

7.110.1 Detailed Description

Defines a 3-Node (P_1) triangle.
The reference element is the rectangle triangle with two unit edges.

Author

Rachid Touzani

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7.110.2 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.

7.110.3 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	Label (local) of node
in	s	Natural coordinates of node where to evaluate

std::vector<Point<real_t> > DSh ( ) const

Return partial derivatives of shape functions of element nodes.

Returns

Vector of partial derivatives of shape functions *e.g.* `dsh`[i-1].x, `dsh`[i-1].y, are partial derivatives of the i-th shape function.

real_t check ( ) const

Check element area and number of nodes.

Returns

- $>$ 0: m is the length
- = 0: zero length (=> Error)

Point<real_t> Grad (const LocalVect< real_t, 3 > & *u*) const

Return constant gradient vector in triangle.

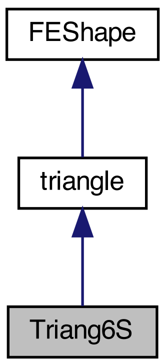
Parameters

in	u	Local vector for which the gradient is evaluated

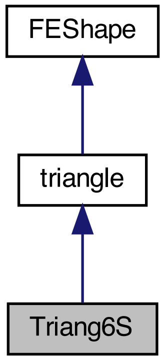
7.111 Triang6S Class Reference

Defines a 6-Node straight triangular finite element using P_2 interpolation.

Inheritance diagram for Triang6S:



Collaboration diagram for Triang6S:



Public Member Functions

- Triang6S ()
  Default Constructor.
- Triang6S (const Element *el)
  Constructor for an element.
- ~Triang6S ()
  Destructor.
- void Sh (real_t s, real_t t, real_t *sh) const
  Calculate shape functions.
- Point< real_t > getCenter () const
  Return coordinates of center of element.
- real_t getMaxEdgeLength () const
  Return maximal edge length of triangle.
- real_t getMinEdgeLength () const
  Return minimal edge length of triangle.
- void setLocal (real_t s, real_t t)
  Initialize local point coordinates in element.
- void atMidEdges (std::vector< Point< real_t > > &dsh, std::vector< real_t > &w)
  Compute partial derivatives of shape functions at mid edges of triangles.
- std::vector< Point< real_t > > DSh () const
  Return partial derivatives of shape functions of element nodes.

7.111.1 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

7.111.2 Constructor & Destructor Documentation

Triang6S (const Element ∗ *el*)

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

Parameters

in	*el*	Pointer to Element instance

7.111.3 Member Function Documentation

void Sh (real_t *s*, real_t *t*, real_t ∗ *sh*) const

Calculate shape functions.

Parameters

in	*s*	Local first coordinate of the point where the gradient of the shape functions are evaluated
in	*t*	Local second coordinate of the point where the gradient of the shape functions are evaluated
out	*sh*	Array of of shape functions at (s,t)

void setLocal (real_t *s*, real_t *t*)

Initialize local point coordinates in element.

Parameters

in	*s*	Local first coordinate of the point where the gradient of the shape functions are evaluated
in	*t*	Local second coordinate of the point where the gradient of the shape functions are evaluated

void atMidEdges (std::vector< Point< real_t > > & *dsh*, std::vector< real_t > & *w*)

Compute partial derivatives of shape functions at mid edges of triangles.

This member function can be called for integrations using partial derivatives of shape functions and approximated by midedge integration formula

Parameters

out	*dsh*	Vector containing partial derivatives of shape functions
out	*w*	Vector containing weights for the integration formula

std::vector<Point<real_t> > DSh ( ) const

Return partial derivatives of shape functions of element nodes.

Returns

LocalVect instance of partial derivatives of shape functions *e.g.* `dsh(i).x`, `dsh(i).y`, are partial derivatives of the *i*-th shape function.

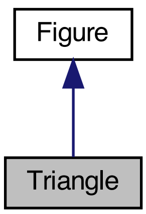
Note

The local point at which the derivatives are computed must be chosen before by using the member function setLocal

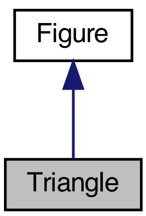
7.112 Triangle Class Reference

To store and treat a triangle.

Inheritance diagram for Triangle:



Collaboration 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 ∗=.

7.112.1 Detailed Description

To store and treat a triangle.

7.112.2 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	*v1*	Coordinates of first vertex of triangle
in	*v2*	Coordinates of second vertex of triangle
in	*v3*	Coordinates of third vertex of triangle
in	*code*	Code to assign to the generated figure [Default: 1]

Remarks

Vertices must be given in couterclockwise order

7.112.3 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	p	Point<double> instance

Reimplemented from Figure.

Triangle& operator+= (Point< real_t > *a*)

Operator +=.

Translate triangle by a vector a

Triangle& operator+= (real_t *a*)

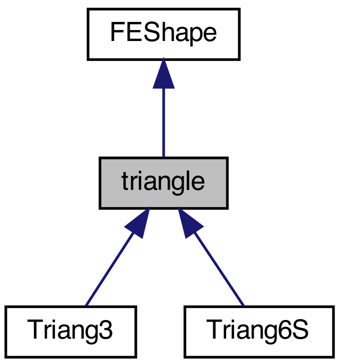
Operator ∗=.

Scale triangle by a factor a

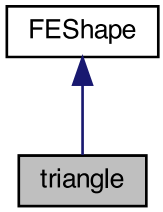
7.113 triangle Class Reference

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

Inheritance diagram for triangle:



Collaboration diagram for triangle:



Public Member Functions

- triangle ()

  Default Constructor.
- triangle (const Element ∗el)

  Constructor for an element.
- triangle (const Side ∗sd)

  Constructor for a side.
- virtual ∼triangle ()

  Destructor.
- real_t getArea ()

  Return element area.
- Point< real_t > getCenter () const

  Return coordinates of center of element.
- Point< real_t > getCircumcenter () const

  Return coordinates of circumcenter of element.
- real_t getCircumRadius () const

  Return radius of circumscribed circle of triangle.
- real_t getInRadius () const

  Return radius of inscribed circle of triangle.
- Point< real_t > getRefCoord (const Point< real_t > &x) const

  Return reference coordinates of a point x *in element.*
- real_t getMaxEdgeLength () const

  Return maximal edge length of triangle.
- real_t getMinEdgeLength () const

  Return minimal edge length of triangle.
- bool isIn (const Point< real_t > &x) const

  Check whether point x *is in current triangle or not.*
- bool isStrictlyIn (const Point< real_t > &x) const

  Check whether point x *is strictly in current triangle (not on the boundary) or not.*

7.113.1 Detailed Description

Defines a triangle. The reference element is the rectangle triangle with two unit edges.

Author

Rachid Touzani

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7.113.2 Constructor & Destructor Documentation

triangle (const Element $*$ ***el*** **)**

Constructor for an element.

The constructed triangle is an element in a 2-D mesh.

triangle (const Side $*$ ***sd*** **)**

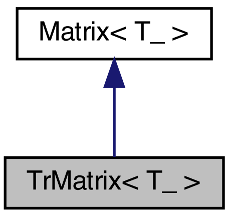
Constructor for a side.

The constructed triangle is a side in a 3-D mesh.

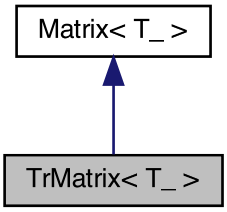
7.114 TrMatrix< T_ > Class Template Reference

To handle tridiagonal matrices.

Inheritance diagram for TrMatrix< T_ >:



Collaboration 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 diagona one and assign value `a` *to all diagonal entries.*
- void Laplace1D (real_t h)

  Define matrix as the one of 3-point finite difference discretization of the second derivative.
- 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 Axpy (T_ a, const TrMatrix< 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 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, bool fact=true)
  Solve a linear system with current matrix (forward and back substitution).
- int solve (const Vect< T_ > &b, Vect< T_ > &x, bool fact=false)
  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.

7.114.1 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 `is` 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_*	Data type (double, float, complex<double>, ...)

Author

Rachid Touzani

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7.115 Vect< T_ > Class Template Reference

To handle general purpose vectors.

Inherits vector< T_ >.

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 nx, size_t ny, size_t nz, size_t nt)

  Constructor of a 4-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, DOFSupport dof_type=NODE_DOF, int nb_dof=0)

  Constructor with a mesh instance.
- Vect (Mesh &m, DOFSupport dof_type, string name, int nb_dof=0, real_t t=0.0)

  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 ()

  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, DOFSupport dof_type=NODE_DOF, size_t nb_dof=0)

  Define mesh class to size vector.
- void setGrid (Grid &g)

  Define grid 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, size_t nt=1)

  Set vector size (for 1-D, 2-D or 3-D cases and 3-D + time)
- 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 (DOFSupport 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.
- DOFSupport 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 Norm (NormType t) const

  Compute a norm 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.
- size_t getNt () const

  Return number of grid points in the t-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 setIJKL (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)

  Assign a given value to components of vector with given code.
- void setNodeBC (Mesh &m, int code, T_ val)

  Assign a given value to components of vector with given code.
- void setSideBC (Mesh &m, int code, T_ val, size_t dof)

  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)

  Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.
- void setNodeBC (Mesh &m, int code, const string &exp)

  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)

  Assign a given function (given by an interpretable algebraic expression) to components of vector corresponding to sides with given code.
- void setSideBC (Mesh &m, int code, const string &exp)

  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)

  Assign a given value to components of vector with given code.
- void setNodeBC (int code, T_ val)

  Assign a given value to components of vector with given code.
- void setNodeBC (int code, const string &exp, size_t dof)

  Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.
- void setNodeBC (int code, const string &exp)

  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)

  Assign a given function (given by an interpre<table algebraic expression) to components of vector with given code.

- void setSideBC (int code, const string &exp)

  Assign a given function (given by an interpre<table algebraic expression) to components of vector with given code.
- void setSideBC (int code, T_ val, size_t dof)

  Assign a given value to components of vector with given code.
- void setSideBC (int code, T_ val)

  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, const 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, 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).
- T_ & operator() (size_t i, size_t j, size_t k, size_t l)

  Operator () with 4-D indexing (Non constant version).
- T_ operator() (size_t i, size_t j, size_t k, size_t l) const

  Operator () with 4-D indexing (Constant version).
- Vect< T_ > & operator= (const Vect< T_ > &v)

  Operator = between vectors.
- 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.

7.115.1 Detailed Description

template<class T_>class OFELI::Vect< T_ >

To handle general purpose vectors.

Author

    Rachid Touzani

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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 `x` the number of degrees of freedom by node. If the degrees of freedom are supported by elements or sides, then the vector is sized accordingly

Operators =, [] and () are overloaded so that one can write for instance:

```
Vect<real_t> u(10), v(10);
v = -1.0;
u = v;
u(3) = -2.0;
```

to set vector **v** entries to **-1**, copy vector **v** into vector **u** and assign third entry of **v** to **-2**. Note that entries of **v** are here **v(1)**, **v(2)**, ..., **v(10)**, *i.e.* vector entries start at index **1**.

Template Parameters

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

7.115.2 Constructor & Destructor Documentation

Vect (size_t *n*)

Constructor setting vector size.
Parameters

in	*n*	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	*nx*	Size for the first index
in	*ny*	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	*nx*	Size for the first index
in	*ny*	Size for the second index
in	*nz*	Size for the third index

Remarks

The size of resulting vector is nx∗ny∗nz

Vect (size_t *nx*, size_t *ny*, size_t *nz*, size_t *nt*)

Constructor of a 4-D index vector.
This constructor can be used for instance for a 4-D grid vector
Parameters

in	*nx*	Size for the first index
in	*ny*	Size for the second index
in	*nz*	Size for the third index

in	*nt*	Size for the fourth index

Remarks

The size of resulting vector is nx∗ny∗nz∗nt

Vect (size_t *n*, T_ ∗ *x*)

Create an instance of class Vect as an image of a C/C++ array.

Parameters

in	*n*	Dimension of vector to construct
in	*x*	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	*g*	Grid instance

Vect (Mesh & *m*, DOFSupport *dof_type* = `NODE_DOF`, int *nb_dof* = `0`)

Constructor with a mesh instance.

Parameters

in	*m*	Mesh instance
in	*dof_type*	Type of degrees of freedom. To be given among the enumerated values: `NODE_DOF`, `ELEMENT_DOF`, `SIDE_DOF` or `EDGE_DOF` (Default↩ : `NODE_DOF`)
in	*nb_dof*	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 Mesh instance

Vect (Mesh & *m*, DOFSupport *dof_type*, string *name*, int *nb_dof* = `0`, real_t *t* = `0.0`)

Constructor with a mesh instance giving name and time for vector.

Parameters

in	*m*	Mesh instance
in	*dof_type*	Type of degrees of freedom. To be given among the enumerated values: `NODE_DOF`, `ELEMENT_DOF`, `SIDE_DOF` or `EDGE_DOF`
in	*name*	Name of the vector
in	*nb_dof*	Number of degrees of freedom per node, element or side If `nb↩_dof` is set to `0` the constructor picks this number from the Mesh instance

in	*t*	Time value for the vector [Default `0.0`]

Vect (const Element ∗ *el*, const Vect< T_ > & *v*)

Constructor of an element vector.

The constructed vector has local numbering of nodes

Parameters

in	*el*	Pointer to Element to localize
in	*v*	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	*sd*	Pointer to Side to localize
in	*v*	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	*v*	Vect instance to update
in	*bc*	Vect 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	*v*	Vect instance to extract from
in	*nb_dof*	Number of DOF to extract
in	*first_dof*	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

Vect (const Vect< T_ > & *v*, size_t *n*)

Constructor to select one component from a given 2 or 3-component vector.

Parameters

in	*v*	Vect instance to extract from
in	*n*	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	*d*	Integer number giving the list of degrees of freedom. This number is made of `n` digits where `n` is the number of degrees of freedom. Let us give an example: Assume that the instance `v` has 3 DOF by entity (node, element or side). The choice `d=201` means that the constructed instance has 2 DOF where the first DOF is the third one of `v`, and the second DOF is the first one of f `v`. Consequently, no digit can be larger than the number of DOF the constructed instance. In this example, a choice `d=103` would produce an error message.
in	*v*	Vect instance from which extraction is performed.
in	*name*	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 !!

7.115.3 Member Function Documentation

void set (const T_ ∗ *v*, size_t *n*)

Initialize vector with a c-array.

Parameters

in	*v*	c-array (pointer) to initialize Vect
in	*n*	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	*v*	Vect instance to extract from
in	*nb_dof*	Number of DOF per node, element or side (By default, 0: Number of degrees of freedom extracted from the Mesh instance)
in	*first_dof*	First DOF to extract (Default: 1) For instance, a choice `first_dof=2` and `nb_dof=1` means that the second DOF of each node is copied in the vector

void set (const string & *exp*, size_t *dof* = 1)

Initialize vector with an algebraic expression.

This function is to be used is a Mesh instance is associated to the vector

Parameters

in	*exp*	Regular algebraic expression that defines a function of `x`, `y`, `z` which are coordinates of nodes and `t` which is the time value.
in	*dof*	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	*exp*	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.

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.

Parameters

in	*x*	Vector that defines coordinates

void set (Mesh & *ms*, const string & *exp*, size_t *dof* = *1*)

Initialize vector with an algebraic expression with providing mesh data.
Parameters

in	*ms*	Mesh instance
in	*exp*	Regular algebraic expression that defines a function of x, y and z which are coordinates of nodes.
in	*dof*	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	*x*	Vect instance that contains coordinates of points
in	*exp*	Regular algebraic expression that defines a function of `x` and `i` which are coordinates. Consider for instance that we want to initialize the Vect instance with the values v[i] = exp(1+x[i]); then, we use this member function as follows v.set("exp("1+x",x);

void setMesh (Mesh & *m*, DOFSupport *dof_type* = `NODE_DOF`, size_t *nb_dof* = `0`)

Define mesh class to size vector.

Parameters

in	*m*	Mesh instance
in	*dof_type*	Parameter to precise the type of degrees of freedom. To be chosen among the enumerated values: `NODE_DOF`, `ELEMENT_DOF`, `SIDE_DOF`, `EDGE_DOF` [Default: `NODE_DOF`]
in	*nb_dof*	Number of degrees of freedom per node, element or side. If `nb_dof` is set to `0` the constructor picks this number from the Mesh instance [Default: `0`]

void setGrid (Grid & *g*)

Define grid class to size vector.

Parameters

in	*g*	Grid instance

void setSize (size_t *nx*, size_t *ny* = *1*, size_t *nz* = *1*, size_t *nt* = *1*)

Set vector size (for 1-D, 2-D or 3-D cases and 3-D + time)

This function allocates memory for the vector but does not initialize its components

Parameters

in	*nx*	Number of grid points in `x`-direction
in	*ny*	Number of grid points in `y`-direction [Default: `1`]
in	*nz*	Number of grid points in `z`-direction [Default: `1`]
in	*nt*	Number of grid points in `t`-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	*n*	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	*n*	Size of vector
in	*v*	Value to assign to vector entries

void setDOFType (DOFSupport *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	*dof_type*	Type of degrees of freedom. Value to be chosen among the enumerated values: `NODE_DOF`, `ELEMENT_DOF`, `SIDE_DOF` or `EDGE_DOF`

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	*degree*	Polynomial degree of the DG 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

DOFSupport getDOFType ( ) const

Return DOF type of vector

Returns

dof_type Type of degrees of freedom. Value among the enumerated values: `NODE_DOF`, `EL↩ EMENT_DOF`, `SIDE_DOF` or `EDGE_DOF`

real_t Norm (NormType *t*) const

Compute a norm of vector.

Parameters

in	*t*	Norm type to compute: To choose among enumerate values↩ : NORM1: 1-norm WNORM1: Weighted 1-norm (Discrete L1-norm) NORM2: 2-norm WNORM2: Weighted 2-norm (Discrete L2-norm) NORM_MAX: max norm (Infinity norm)

Returns

Value of norm

Warning

This function is available for real valued vectors only

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	*exp*	Regular algebraic expression to assign. It must involve the variables `i`, `j` and/or `k`.

void setIJKL (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	*exp*	Regular algebraic expression to assign. It must involve the variables `i`, `j`, `k` and/or `l`.

void setNodeBC (Mesh & ***m*****, int** ***code*****, T_** ***val*****, size_t** ***dof*** **)**

Assign a given value to components of vector with given code.
Vector components are assumed nodewise

Parameters

in	*m*	Mesh instance
in	*code*	The value is assigned if the node has this code
in	*val*	Value to assign
in	*dof*	Degree of freedom to assign

void setNodeBC (Mesh & *m*, int *code*, T_ *val*)

Assign a given value to components of vector with given code.

Vector components are assumed nodewise. Here all dofs of nodes with given code will be assigned

Parameters

in	*m*	Mesh instance
in	*code*	The value is assigned if the node has this code
in	*val*	Value to assign

void setSideBC (Mesh & *m*, int *code*, T_ *val*, size_t *dof*)

Assign a given value to components of vector corresponding to sides 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	*val*	Value to prescribe
in	*dof*	Degree of Freedom for which the value is assigned [default: 1]

void setNodeBC (Mesh & *m*, int *code*, const string & *exp*, size_t *dof*)

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

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

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise. Case of 1-DOF problem

Parameters

in	*m*	Instance of mesh
in	*code*	Code for which nodes will be assigned prescribed value
in	*exp*	Regular algebraic expression to prescribe

void setSideBC (Mesh & *m*, int *code*, const string & *exp*, size_t *dof*)

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	*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

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

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. Case of 1-DOF problem

Parameters

in	*m*	Instance of mesh
in	*code*	Code for which nodes will be assigned prescribed value
in	*exp*	Regular algebraic expression to prescribe

void setNodeBC (int *code*, T_ *val*, size_t *dof*)

Assign a given value to components of vector with given code.

Vector components are assumed nodewise

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*val*	Value to prescribe
in	*dof*	Degree of Freedom for which the value is assigned [default: 1]

void setNodeBC (int *code*, T_ *val*)

Assign a given value to components of vector with given code.

Vector components are assumed nodewise. Concerns 1-DOF problems

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*val*	Value to prescribe

void setNodeBC (int *code*, const string & *exp*, size_t *dof*)

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

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]

Warning

This member function is to be used in the case where a constructor with a Mesh has been used

void setNodeBC (int *code*, const string & *exp*)

Assign a given function (given by an interpretable algebraic expression) to components of vector with given code.

Vector components are assumed nodewise. Concerns 1-DOF problems

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*exp*	Regular algebraic expression to prescribe

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*)

Assign a given function (given by an interpre<table algebraic expression) to components of vector with given code.

Vector components are assumed nodewise

Parameters

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

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*)

Assign a given function (given by an interpre<table algebraic expression) to components of vector with given code.

Vector components are assumed nodewise. Case of 1-DOF problem

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*exp*	Regular algebraic expression to prescribe

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*)

Assign a given value to components of vector with given code.
Vector components are assumed nodewise

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*val*	Value to prescribe
in	*dof*	Degree of Freedom for which the value is assigned

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*)

Assign a given value to components of vector with given code.
Vector components are assumed nodewise. Concerns 1-DOF problems

Parameters

in	*code*	Code for which nodes will be assigned prescribed value
in	*val*	Value to prescribe

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	*ms*	Mesh instance
in	*v*	Vector (Vect instance to copy from)
in	*dof*	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

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	*v*	Vector (Vect instance to copy from)
in	*dof*	Parameter to say if all degrees of freedom are concerned [Default: `0`] or if only one degree of freedom (`dof`) is inserted into vector `v` 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	*bc*	Vect instance from which imposed degrees of freedom are copied to current instance
in	*dof*	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.

void insertBC (Mesh & *m*, const Vect< T_ > & *v*, const Vect< T_ > & *bc*, int *dof* = 0)

Insert boundary conditions.

Parameters

in	*m*	Mesh instance.
in	*v*	Vect instance from which free degrees of freedom are copied to current instance.
in	*bc*	Vect instance from which imposed degrees of freedom are copied to current instance.
in	*dof*	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 (Mesh & *m*, const Vect< T_ > & *v*, int *dof* = 0)

Insert boundary conditions.

DOF with imposed boundary conditions are set to zero.

Parameters

in	*m*	Mesh instance.
in	*v*	Vect instance from which free degrees of freedom are copied to current instance.
in	*dof*	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	*v*	Vect instance from which free degrees of freedom are copied to current instance.
in	*bc*	Vect instance from which imposed degrees of freedom are copied to current instance.
in	*dof*	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	*v*	Vect instance from which free degrees of freedom are copied to current instance.
in	*dof*	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	*el*	Reference to Element instance
in	*b*	Local vector to assemble (Instance of class Vect)

void Assembly (const Element & *el*, const T_ * *b*)

Assembly of element vector (as C-array) into Vect instance.

Parameters

in	*el*	Reference to Element instance
in	*b*	Local vector to assemble (C-Array)

void Assembly (const Side & *sd*, const Vect< T_ > & *b*)

Assembly of side vector into Vect instance.

Parameters

in	*sd*	Reference to Side instance
in	*b*	Local vector to assemble (Instance of class Vect)

void Assembly (const Side & *sd*, const T_ ∗ *b*)

Assembly of side vector (as C-array) into Vect instance.

Parameters

in	*sd*	Reference to Side instance
in	*b*	Local vector to assemble (C-Array)

void getGradient (class Vect< T_ > & *v*)

Evaluate the discrete Gradient vector of the current vector.

The resulting gradient is stored in a Vect instance. This function handles node vectors assuming P_1 approximation. The gradient is then a constant vector for each element.

Parameters

in	*v*	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_1 approximation. The gradient is then a constant vector for each element.

Parameters

in	*v*	Vect instance that contains the gradient, where `v(n,1).x`, `v(n,2).y` and `v(n,3).z` are respectively the `x` and `y` and `z` derivatives at element `n`.

void getCurl (Vect< T_ > & *v*)

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a Vect instance. This function handles node vectors assuming P_1 approximation. The curl is then a constant vector for each element.

Parameters

in	*v*	Vect instance that contains the curl, where `v(n,1)`, `v(n,2)` and `v(n,3)` are respectively the `x` and `y` and `z` `curl` components at element `n`.

void getCurl (Vect< Point< T_ > > & *v*)

Evaluate the discrete curl vector of the current vector.

The resulting curl is stored in a Vect instance. This function handles node vectors assuming P_1 approximation. The curl is then a constant vector for each element.

Parameters

in	*v*	Vect instance that contains the curl, where `v(n,1).x`, `v(n,2).y` and `v(n,3).z` are respectively the `x` and `y` and `z` `curl` components at element `n`.

void getSCurl (Vect< T_ > & *v*)

Evaluate the discrete scalar curl in 2-D of the current vector.

The resulting curl is stored in a Vect instance. This function handles node vectors assuming P_1 approximation. The curl is then a constant vector for each element.

Parameters

in	*v*	Vect instance that contains the scalar curl.

void getDivergence (Vect< T_ > & *v*)

Evaluate the discrete Divergence of the current vector.

The resulting divergence is stored in a Vect instance. This function handles node vectors assuming P_1 approximation. The divergence is then a constant vector for each element.

Parameters

in	*v*	Vect instance that contains the divergence.

real_t getAverage (const Element & *el*, int *type*) const

Return average value of vector in a given element.

Parameters

in	*el*	Element instance
in	*type*	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	*x*	Vect instance to add
in	*a*	Constant to multiply before adding

void Axpy (T_ *a*, const Vect< T_ > & *x*)

Add to vector the product of a vector by a scalar.

Parameters

in	*a*	Scalar to premultiply
in	*x*	Vect instance by which a 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*	Rank index in vector (starts at 1)
in	*val*	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*	First index in vector (starts at 1)
in	*j*	Second index in vector (starts at 1)
in	*val*	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*	First index in vector (starts at 1)
in	*j*	Second index in vector (starts at 1)
in	*k*	Third index in vector (starts at 1)
in	*val*	Value to assign

void add (size_t *i*, T_ *val*)

Add a value to an entry for a 1-index vector.
Parameters

in	*i*	Rank index in vector (starts at 1)
in	*val*	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*	First index in vector (starts at 1)
in	*j*	Second index in vector (starts at 1)
in	*val*	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*	First index in vector (starts at 1)
in	*j*	Second index in vector (starts at 1)
in	*k*	Third index in vector (starts at 1)
in	*val*	Value to assign

T_& operator() (size_t *i*)

Operator `()` (Non constant version)
Parameters

in	*i*	Rank index in vector (starts at 1) • `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)
Parameters

`in`	*i*	Rank index in vector (starts at 1) • `v(i)` starts at `v(1)` to `v(size())` • `v(i)` is the same element as `v[i-1]`

T_& operator() (size_t *i*, size_t *j*)

Operator `()` with 2-D indexing (Non constant version, case of a grid vector).
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) `v(i,j)` starts at `v(1,1)` to `v(getNx(),getNy())`

T_ operator() (size_t *i*, size_t *j*) const

Operator `()` with 2-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) `v(i,j)` starts at `v(1,1)` to `v(getNx(),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(getNx(),getNy(),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(getNx(),getNy(),getNz())`

T_& operator() (size_t *i*, size_t *j*, size_t *k*, size_t *l*)

Operator () with 4-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)
in	*l*	fourth index in vector (Number of vector components in the t-grid) `v(i,j,k,l)` starts at `v(1,1,1,1)` to `v(getNx(),getNy(),getNz(),getNt())`

T_ operator() (size_t *i*, size_t *j*, size_t *k*, size_t *l*) const

Operator `()` with 4-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)
in	*l*	third index in vector (Number of vector components in the t-grid) `v(i,j,k,l)` starts at `v(1,1,1,1)` to `v(getNx(),getNy(),getNz(),getNt())`

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	*s*	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	*vmin*	Minimal value to assign to the first entry
in	*vmax*	Maximal value to assign to the lase entry
in	*n*	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	*a*	Value to set

Vect<T_>& operator+= (const Vect< T_ > & *v*)

Operator +=

Add vector x to current vector instance.

Parameters

in	*v*	Vect instance to add to instance

Vect<T_>& operator+= (const T_ & *a*)

Operator +=

Add a constant to current vector entries.

Parameters

in	*a*	Value to add to vector entries

Vect<T_>& operator-= (const Vect< T_ > & *v*)

Operator -=

Parameters

in	*v*	Vect instance to subtract from

Vect<T_>& operator-= (const T_ & *a*)

Operator -=

Subtract constant from vector entries.

Parameters

in	*a*	Value to subtract from

Vect<T_>& operator*= (const T_ & *a*)

Operator *=

Parameters

in	*a*	Value to multiply by

Vect<T_>& operator/= (const T_ & *a*)

Operator /=

Parameters

in	*a*	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	v	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	Vect 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^MA←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

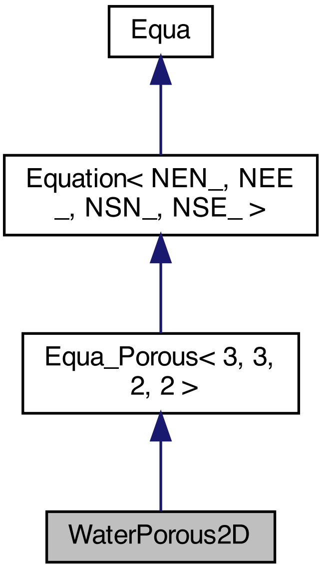
Remarks

The size of Vect instance must be a power of two and must not exceed the value of 2^MA←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> >

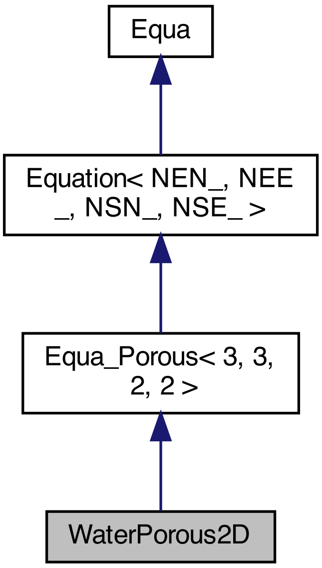
7.116 WaterPorous2D Class Reference

To solve water flow equations in porous media (1-D)

Inheritance diagram for WaterPorous2D:



Collaboration diagram for WaterPorous2D:



Public Member Functions

- WaterPorous2D ()

    Default Constructor.
- WaterPorous2D (Mesh &ms)

    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)

    Add source right-hand side term to right-hand side.
- void BoundaryRHS (const Vect< real_t > &sf)

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

Additional Inherited Members

7.116.1 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.

7.116.2 Constructor & Destructor Documentation

WaterPorous2D ( )

Default Constructor.

Constructs an empty equation.

WaterPorous2D (Mesh & *ms*)

Constructor.

This constructor uses mesh and reservoir information

Parameters

in	*ms*	Mesh instance

7.116.3 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	*cw*	Compressibility coefficient
in	*phi*	Porosity
in	*rho*	Density
in	*Kx*	x-Absolute permeability
in	*Ky*	y-Absolute permeability
in	*mu*	Viscosity

void BodyRHS (const Vect< real_t > & *bf*) `[virtual]`

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

Parameters

in	*bf*	Vector containing source at nodes.

Reimplemented from Equa_Porous< 3, 3, 2, 2 >.

void BoundaryRHS (const Vect< real_t > & *sf*) `[virtual]`

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

Parameters

`in`	*sf*	Vector containing source at nodes.

Reimplemented from Equa_Porous< 3, 3, 2, 2 >.

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