# MTK: Mimetic Methods Toolkit

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# Contents

# Chapter 1

# Introduction

We define numerical methods that are based on discretizations preserving the properties of their continuum counterparts to be **mimetic**.

The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical methods. It is arranged as a set of classes for **mimetic quadratures**, mimetic interpolation$**$, and **mimetic finite differences** methods for the numerical solution of ordinary and partial differential equations.

## 1.1 MTK Concerns

Since collaborative development efforts are definitely important in achieving the level of generality we intend the library to possess, we have divided the library's source code according to the designated purpose the classes possess within the library. These divisions (or **concerns**) are grouped by layers, and are hierarchically related by the dependence they have among them.

One concern is said to depend on another one, if the classes the first concern includes, rely on the classes the second concern includes.

In order of dependence these are:

1. Roots.
2. Enumerations.
3. Tools.
4. Data Structures.
5. Numerical Methods.
6. Grids.
7. Mimetic Operators.

## 1.2 MTK Flavors

The MTK collection of wrappers is:

1. MMTK: MATLAB wrappers collection for MTK; intended for sequential computations.

Others are being strongly considered.

## 1.3 Contact, Support and Credits

The MTK is developed by researchers and adjuncts to the Computational Science Research Center (CSRC) at San Diego State University (SDSU).

Developers are members of:

1. Mimetic Numerical Methods Research and Development Group.
2. Computational Geoscience Research and Development Group.
3. Ocean Modeling Research and Development Group.

Currently the developers are:

1. **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - ejspeiro
2. Jose E. Castillo, Ph.D. - jcastillo at mail dot sdsu dot edu
3. Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
4. Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
5. Angel Boada.
6. Johnny Corbino.
7. Raul Vargas–Navarro.

## 1.4 Acknowledgements and Contributions

The authors would like to acknowledge valuable advising, contributions and feedback, from research personnel at the Computational Science Research Center at San Diego State University, which were vital to the fruition of this work. Specifically, our thanks go to (alphabetical order):

1. Mohammad Abouali, Ph.D.
2. Dany De Cecchis, Ph.D.
3. Otilio Rojas, Ph.D.
4. Julia Rossi.

# Chapter 2

# Programming Tools

The development of MTK has been made possible through the use of the following applications:

1. Editor: Kate - KDE Advanced Text Editor. Version 3.13.3. Using KDE Development Platform 4.13.3 (C) 2000-2005 The Kate Authors.
2. Debugger: GNU gdb (Ubuntu 7.7.1-0ubuntu5~14.04.2) 7.7.1. Copyright (C) 2014 Free Software Foundation, Inc.
3. Memory Profiler: valgrind-3.10.0.SVN.

See the section on test architectures for information about operating systems and compilers used.

# Chapter 3

# Licensing and Modifications



Redistribution and use in source and binary forms, with or without modification, are permitted provided that the following conditions are met:

1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu and a copy of the modified files should be reported once modifications are completed, unless these modifications are made through the project's GitHub page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications should be developed and included in any deliverable.
2. Redistributions of source code must be done through direct downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
3. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
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THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

# Chapter 4

# Read Me File and Installation Instructions

## README File for the Mimetic Methods Toolkit (MTK)

By: **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu**

### 1. Description

We define numerical methods that are based on discretizations preserving the properties of their continuum counterparts to be **mimetic.**

The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical methods. It is arranged as a set of classes for **mimetic quadratures**, **mimetic interpolation**, and **mimetic finite differences** methods for the numerical solution of ordinary and partial differential equations.

### 2. Dependencies

This README assumes all of these dependencies are installed in the following folder:

$(HOME)/Libraries/

In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK routines for the internal computation on some of the layers. However, ATLAS requires both BLAS and LAPACK in order to create their optimized distributions. Therefore, the following dependencies tree arises:

**For Linux:**

1. LAPACK - Available from: http://www.netlib.org/lapack/
   1. BLAS - Available from: http://www.netlib.org/blas/

2. GLPK - Available from: https://www.gnu.org/software/glpk/

3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
   1. LAPACK - Available from: http://www.netlib.org/lapack/
      1. BLAS - Available from: http://www.netlib.org/blas

4. (Optional) Valgrind - Available from: http://valgrind.org/

5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/

**For OS X:**

1. GLPK - Available from: https://www.gnu.org/software/glpk/

## 3. Installation

**PART 1. CONFIGURATION OF THE MAKEFILE.**

The following steps are required the build and test the MTK. Please use the accompanying Makefile.inc file, which should provide a solid template to start with. The following command provides help on the options for make:

```
$ make help
-----
Makefile for the MTK.

Options are:
- all: builds the library, the tests, and examples.
- mtklib: builds the library.
- test: builds the test files.
- example: builds the examples.

- testall: runs all the tests.

- gendoc: generates the documentation for the library.

- clean: cleans all the generated files.
- cleanlib: cleans the generated archive and object files.
- cleantest: cleans the generated tests executables.
- cleanexample: cleans the generated examples executables.
-----
```

**PART 2. BUILD THE LIBRARY.**

```
$ make
```

If successful you'll read (before building the examples):

```
----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
```

## 4. Contact, Support, and Credits

The MTK is developed by researchers and adjuncts to the
Computational Science Research Center (CSRC)
at San Diego State University (SDSU).

Developers are members of:

1. Mimetic Numerical Methods Research and Development Group.
2. Computational Geoscience Research and Development Group.
3. Ocean Modeling Research and Development Group.

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1. **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - ejspeiro
2. Jose E. Castillo, Ph.D. - jcastillo at mail dot sdsu dot edu
3. Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
4. Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
5. Angel Boada.
6. Johnny Corbino.
7. Raul Vargas-Navarro.

Finally, please feel free to contact me with suggestions or corrections:

**Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - ejspeiro

Thanks and happy coding!

# Chapter 5

# Tests and Test Architectures

Tests are given in the `files list` section. They are provided in the /tests/ folder within the distributed software.

In this page we intend to make a summary of all of the architectures in where the MTK has been tested. The MTK is intended to be as portable as possible throughout architectures. The following architectures have provided flawless installations of the API and correct execution of the examples:

1. Intel(R) Pentium(R) M CPU 1.73 GHz 2048 KB of cache and stepping of 8.
   Linux 3.2.0-23-generic-pae #36-Ubuntu SMP i386 GNU/Linux
   gcc version 4.6.3 (Ubuntu/Linaro 4.6.3-1ubuntu5)

2. Intel(R) Core(TM) i7-4700MQ CPU 2.40 GHz 6144 KB of cache and stepping of 3.
   Linux 3.13.0-67-generic #110-Ubuntu SMP x86_64 GNU/Linux
   gcc version 4.8.4 (Ubuntu 4.4.4-2ubuntu1~14.04)

3. Intel(R) Core(TM) i7-4600U CPU 2.10 GHz 4096 KB of cache and a stepping of 1.
   Linux 3.16.7-29-desktop #1 SMP PREEMPT (6be6a97) x86_64 GNU/Linux
   openSUSE 13.2 (Harlequin) (x86_64)
   gcc (SUSE Linux) 4.8.3 20140627 [gcc-4_8-branch revision 212064]

Further architectures will be tested!

# Chapter 6

# Examples

Examples are given in the `files list` section. They are provided in the /examples/ folder within the distributed software.

# Chapter 7

# User Manual, References and Theory

The main source of references for this work can be found in:

http://www.csrc.sdsu.edu/mimetic-book/

However, a .PDF copy of this manual can be found here.

# Chapter 8

# Todo List

**Member mtk::DenseMatrix::Kron (const DenseMatrix &aa, const DenseMatrix &bb)**

Implement Kronecker product using the BLAS.

**Member mtk::DenseMatrix::OrderColMajor ()**

Improve this so that no new arrays have to be created.

**Member mtk::DenseMatrix::OrderRowMajor ()**

Improve this so that no new arrays have to be created.

**Member mtk::DenseMatrix::Transpose ()**

Improve this so that no extra arrays have to be created.

**Class mtk::GLPKAdapter**

Rescind from the GLPK as the numerical core for CLO problems.

**Member mtk::Matrix::IncreaseNumNull () noexcept**

Review the definition of sparse matrices properties.

**Member mtk::Matrix::IncreaseNumZero () noexcept**

Review the definition of sparse matrices properties.

**Member mtk::RobinBCDescriptor2D::ImposeOnGrid (UniStgGrid2D &grid, const Real &time=kZero) const**

Implement imposition for vector-valued grids. Need research here!

**Member mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryNoSpace (const Lap2D &lap, const UniStg↩ Grid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const**

Impose the Neumann conditions on every pole, for every scenario.

**Member mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryWithSpace (const Lap2D &lap, const UniStg↩ Grid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const**

Impose Harmonic mean on the corners for the case when the generated space is available, for all poles.

**Member mtk::Tools::Prevent (const bool complement, const char ∗const fname, int lineno, const char ∗const fxname) noexcept**

Check if this is the best way of stalling execution.

**Member mtk::Tools::test_number_**

Check usage of static methods and private members.

**Member mtk::UniStgGrid1D::discrete_domain_x () const**

Review const-correctness of the pointer we return.

**Member mtk::UniStgGrid1D::discrete_field ()**

Review const-correctness of the pointer we return. Look at the STL!

**Member mtk::UniStgGrid2D::discrete_domain_x () const**

Review const-correctness of the pointer we return.

**Member mtk::UniStgGrid2D::discrete_domain_y () const**

Review const-correctness of the pointer we return.

**Member mtk::UniStgGrid3D::discrete_domain_x () const**

Review const-correctness of the pointer we return.

**Member mtk::UniStgGrid3D::discrete_domain_y () const**

Review const-correctness of the pointer we return.

**Member mtk::UniStgGrid3D::discrete_domain_z () const**

Review const-correctness of the pointer we return.

**File mtk_div_1d.cc**

Overload ostream operator as in mtk::Lap1D.

Implement creation of ■ w. mtk::BLASAdapter.

**File mtk_glpk_adapter_test.cc**

Test the mtk::GLPKAdapter class.

**File mtk_grad_1d.cc**

Overload ostream operator as in mtk::Lap1D.

Implement creation of ■ w. mtk::BLASAdapter.

**File mtk_lapack_adapter.cc**

Write documentation using LaTeX.

**File mtk_lapack_adapter_test.cc**

Test the mtk::LAPACKAdapter class.

**File mtk_quad_1d.h**

Implement this class.

**File mtk_roots.h**

Documentation should (better?) capture effects from selective compilation.

Test selective precision mechanisms.

**File mtk_uni_stg_grid_1d.h**

Create overloaded binding routines that read data from files.

**File mtk_uni_stg_grid_2d.h**

Create overloaded binding routines that read data from files.

**File mtk_uni_stg_grid_3d.h**

Create overloaded binding routines that read data from files.

# Chapter 9

# Bug List

**Member mtk::Matrix::set_num_null (const int &in) noexcept**

-nan assigned on construction time due to num_values_ being 0.

**Member mtk::Matrix::set_num_zero (const int &in) noexcept**

-nan assigned on construction time due to num_values_ being 0.

# Chapter 10

# Module Index

## 10.1 Modules

Here is a list of all modules:

# Chapter 11

# Namespace Index

## 11.1 Namespace List

Here is a list of all namespaces with brief descriptions:

# Chapter 12

# Class Index

## 12.1 Class List

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

# Chapter 13

# File Index

## 13.1 File List

Here is a list of all files with brief descriptions:

# Chapter 14

# Module Documentation

## 14.1 Roots.

Fundamental execution parameters and defined types.

### Typedefs

- typedef float mtk::Real

  *Users can simply change this to build a double- or single-precision MTK.*

### Variables

- const float mtk::kZero {0.0f}

  *MTK's zero defined according to selective compilation.*
- const float mtk::kOne {1.0f}

  *MTK's one defined according to selective compilation.*
- const float mtk::kTwo {2.0f}

  *MTK's two defined according to selective compilation.*
- const float mtk::kDefaultTolerance {1e-7f}

  *Considered tolerance for comparisons in numerical methods.*
- const int mtk::kDefaultOrderAccuracy {2}

  *Default order of accuracy for mimetic operators.*
- const float mtk::kDefaultMimeticThreshold {1e-6f}

  *Default tolerance for higher-order mimetic operators.*
- const int mtk::kCriticalOrderAccuracyDiv {8}

  *At this order (and higher) we must use the CBSA to construct.*
- const int mtk::kCriticalOrderAccuracyGrad {10}

  *At this order (and higher) we must use the CBSA to construct.*

### 14.1.1 Detailed Description

Fundamental execution parameters and defined types.

### 14.1.2 Typedef Documentation

#### 14.1.2.1 mtk::Real

Definition at line 83 of file mtk_roots.h.

### 14.1.3 Variable Documentation

#### 14.1.3.1 mtk::kCriticalOrderAccuracyDiv {8}

Definition at line 167 of file mtk_roots.h.

#### 14.1.3.2 mtk::kCriticalOrderAccuracyGrad {10}

Definition at line 176 of file mtk_roots.h.

#### 14.1.3.3 mtk::kDefaultMimeticThreshold {1e-6f}

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 157 of file mtk_roots.h.

#### 14.1.3.4 mtk::kDefaultOrderAccuracy {2}

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 143 of file mtk_roots.h.

#### 14.1.3.5 mtk::kDefaultTolerance {1e-7f}

Definition at line 131 of file mtk_roots.h.

#### 14.1.3.6 mtk::kOne {1.0f}

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 117 of file mtk_roots.h.

#### 14.1.3.7 mtk::kTwo {2.0f}

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 118 of file mtk_roots.h.

#### 14.1.3.8 mtk::kZero {0.0f}

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 116 of file mtk_roots.h.

## 14.2 Enumerations.

Enumerations.

### Enumerations

- enum mtk::MatrixStorage { mtk::DENSE, mtk::BANDED, mtk::CRS }

  *Considered matrix storage schemes to implement sparse matrices.*
- enum mtk::MatrixOrdering { mtk::ROW_MAJOR, mtk::COL_MAJOR }

  *Considered matrix ordering (for Fortran purposes).*
- enum mtk::FieldNature { mtk::SCALAR, mtk::VECTOR }

  *Nature of the field discretized in a given grid.*
- enum mtk::DirInterp { mtk::SCALAR_TO_VECTOR, mtk::VECTOR_TO_SCALAR }

  *Interpolation operator.*

### 14.2.1 Detailed Description

Enumerations.

### 14.2.2 Enumeration Type Documentation

#### 14.2.2.1 enum mtk::DirInterp

Used to tag different directions of interpolation supported.

**Enumerator**

***SCALAR_TO_VECTOR*** Interpolations places scalar on vectors' location.

***VECTOR_TO_SCALAR*** Interpolations places vectors on scalars' location.

Definition at line 127 of file mtk_enums.h.

#### 14.2.2.2 enum mtk::FieldNature

Fields can be **scalar** or **vector** in nature.

**See also**

https://en.wikipedia.org/wiki/Scalar_field
https://en.wikipedia.org/wiki/Vector_field

**Enumerator**

***SCALAR*** Scalar-valued field.

***VECTOR*** Vector-valued field.

Definition at line 113 of file mtk_enums.h.

#### 14.2.2.3 enum mtk::MatrixOrdering

Row-major ordering is used for most application in C/C++. For Fortran purposes, the matrices must be listed in a column-major ordering.

**See also**

https://en.wikipedia.org/wiki/Row-major_order

**Enumerator**

***ROW_MAJOR*** Row-major ordering (C/C++).

***COL_MAJOR*** Column-major ordering (Fortran).

Definition at line 95 of file mtk_enums.h.

#### 14.2.2.4 enum mtk::MatrixStorage

The considered sparse storage schemes are selected so that these are compatible with some of the most used mathematical APIs, as follows: DENSE and BANDED for BLAS, LAPACK, and ScaLAPACK. Finally, CRS for SuperLU.

**Enumerator**

***DENSE*** Dense matrices, implemented as a 1D array: DenseMatrix.

***BANDED*** Banded matrices ala LAPACK and ScaLAPACK: Must be implemented.

***CRS*** Compressed-Rows Storage: Must be implemented.

Definition at line 77 of file mtk_enums.h.

## 14.3 Execution tools.

Tools to ensure execution correctness.

### Classes

- class mtk::Tools

  *Tool manager class.*

### 14.3.1 Detailed Description

Tools to ensure execution correctness.

## 14.4 Data structures.

Fundamental data structures.

### Classes

- class mtk::DenseMatrix

  *Defines a common dense matrix, using a 1D array.*
- class mtk::Matrix

  *Definition of the representation of a matrix in the MTK.*

### 14.4.1 Detailed Description

Fundamental data structures.

## 14.5 Numerical methods.

Adapter classes and auxiliary numerical methods.

### Classes

- class mtk::BLASAdapter

  *Adapter class for the BLAS API.*
- class mtk::GLPKAdapter

  *Adapter class for the GLPK API.*
- class mtk::LAPACKAdapter

  *Adapter class for the LAPACK API.*

### 14.5.1 Detailed Description

Adapter classes and auxiliary numerical methods.

## 14.6 Grids.

Uniform rectangular staggered grids.

### Classes

- class mtk::UniStgGrid1D

  *Uniform 1D Staggered Grid.*
- class mtk::UniStgGrid2D

  *Uniform 2D Staggered Grid.*
- class mtk::UniStgGrid3D

  *Uniform 3D Staggered Grid.*

### 14.6.1 Detailed Description

Uniform rectangular staggered grids.

## 14.7 Mimetic operators.

Mimetic operators.

### Classes

- class mtk::Curl2D

  *Implements a 2D mimetic curl operator.*
- class mtk::Div1D

  *Implements a 1D mimetic divergence operator.*
- class mtk::Div2D

  *Implements a 2D mimetic divergence operator.*
- class mtk::Div3D

  *Implements a 3D mimetic divergence operator.*
- class mtk::Grad1D

  *Implements a 1D mimetic gradient operator.*
- class mtk::Grad2D

  *Implements a 2D mimetic gradient operator.*
- class mtk::Grad3D

  *Implements a 3D mimetic gradient operator.*
- class mtk::Interp1D

  *Implements a 1D interpolation operator.*
- class mtk::Interp2D

  *Implements a 2D interpolation operator.*
- class mtk::Lap1D

  *Implements a 1D mimetic Laplacian operator.*
- class mtk::Lap2D

  *Implements a 2D mimetic Laplacian operator.*
- class mtk::Lap3D

  *Implements a 3D mimetic Laplacian operator.*
- class mtk::Quad1D

  *Implements a 1D mimetic quadrature.*
- class mtk::RobinBCDescriptor1D

  *Impose Robin boundary conditions on the operators and on the grids.*
- class mtk::RobinBCDescriptor2D

  *Impose Robin boundary conditions on the operators and on the grids.*

### Typedefs

- typedef Real(∗ mtk::CoefficientFunction0D )(const Real &tt)

  *A function of a BC coefficient evaluated on a 0D domain and time.*
- typedef Real(∗ mtk::CoefficientFunction1D )(const Real &xx, const Real &tt)

  *A function of a BC coefficient evaluated on a 1D domain and time.*

### 14.7.1 Detailed Description

Mimetic operators.

### 14.7.2 Typedef Documentation

#### 14.7.2.1 mtk::CoefficientFunction0D

**Warning**

This definition implies that, for now, coefficients will depend on space and time, thus no extra parameters can influence their behavior. We will fix this soon enough.

Definition at line 111 of file mtk_robin_bc_descriptor_1d.h.

#### 14.7.2.2 mtk::CoefficientFunction1D

Definition at line 97 of file mtk_robin_bc_descriptor_2d.h.

# Chapter 15

# Namespace Documentation

## 15.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

### Classes

- class BLASAdapter

  *Adapter class for the BLAS API.*
- class Curl2D

  *Implements a 2D mimetic curl operator.*
- class DenseMatrix

  *Defines a common dense matrix, using a 1D array.*
- class Div1D

  *Implements a 1D mimetic divergence operator.*
- class Div2D

  *Implements a 2D mimetic divergence operator.*
- class Div3D

  *Implements a 3D mimetic divergence operator.*
- class GLPKAdapter

  *Adapter class for the GLPK API.*
- class Grad1D

  *Implements a 1D mimetic gradient operator.*
- class Grad2D

  *Implements a 2D mimetic gradient operator.*
- class Grad3D

  *Implements a 3D mimetic gradient operator.*
- class Interp1D

  *Implements a 1D interpolation operator.*
- class Interp2D

  *Implements a 2D interpolation operator.*
- class Lap1D

  *Implements a 1D mimetic Laplacian operator.*

- class Lap2D

  *Implements a 2D mimetic Laplacian operator.*
- class Lap3D

  *Implements a 3D mimetic Laplacian operator.*
- class LAPACKAdapter

  *Adapter class for the LAPACK API.*
- class Matrix

  *Definition of the representation of a matrix in the MTK.*
- class Quad1D

  *Implements a 1D mimetic quadrature.*
- class RobinBCDescriptor1D

  *Impose Robin boundary conditions on the operators and on the grids.*
- class RobinBCDescriptor2D

  *Impose Robin boundary conditions on the operators and on the grids.*
- class Tools

  *Tool manager class.*
- class UniStgGrid1D

  *Uniform 1D Staggered Grid.*
- class UniStgGrid2D

  *Uniform 2D Staggered Grid.*
- class UniStgGrid3D

  *Uniform 3D Staggered Grid.*

## Typedefs

- typedef Real(∗ CoefficientFunction0D )(const Real &tt)

  *A function of a BC coefficient evaluated on a 0D domain and time.*
- typedef Real(∗ CoefficientFunction1D )(const Real &xx, const Real &tt)

  *A function of a BC coefficient evaluated on a 1D domain and time.*
- typedef float Real

  *Users can simply change this to build a double- or single-precision MTK.*

## Enumerations

- enum MatrixStorage { DENSE, BANDED, CRS }

  *Considered matrix storage schemes to implement sparse matrices.*
- enum MatrixOrdering { ROW_MAJOR, COL_MAJOR }

  *Considered matrix ordering (for Fortran purposes).*
- enum FieldNature { SCALAR, VECTOR }

  *Nature of the field discretized in a given grid.*
- enum DirInterp { SCALAR_TO_VECTOR, VECTOR_TO_SCALAR }

  *Interpolation operator.*

## Functions

- float snrm2_ (int *n, float *x, int *incx)
- void saxpy_ (int *n, float *sa, float *sx, int *incx, float *sy, int *incy)
- void sgemv_ (char *trans, int *m, int *n, float *alpha, float *a, int *lda, float *x, int *incx, float *beta, float *y, int *incy)
- void sgemm_ (char *transa, char *transb, int *m, int *n, int *k, double *alpha, double *a, int *lda, double *b, aamm int *ldb, double *beta, double *c, int *ldc)
- std::ostream & operator<< (std::ostream &stream, mtk::DenseMatrix &in)
- std::ostream & operator<< (std::ostream &stream, mtk::Div1D &in)
- std::ostream & operator<< (std::ostream &stream, mtk::Grad1D &in)
- std::ostream & operator<< (std::ostream &stream, mtk::Interp1D &in)
- std::ostream & operator<< (std::ostream &stream, mtk::Lap1D &in)
- void sgesv_ (int *n, int *nrhs, Real *a, int *lda, int *ipiv, Real *b, int *ldb, int *info)
- void sgels_ (char *trans, int *m, int *n, int *nrhs, Real *a, int *lda, Real *b, int *ldb, Real *work, int *lwork, int *info)

  *Single-precision GEneral matrix Least Squares solver.*
- void sgeqrf_ (int *m, int *n, Real *a, int *lda, Real *tau, Real *work, int *lwork, int *info)

  *Single-precision GEneral matrix QR Factorization.*
- void sormqr_ (char *side, char *trans, int *m, int *n, int *k, Real *a, int *lda, Real *tau, Real *c, int *ldc, Real *work, int *lwork, int *info)

  *Single-precision Orthogonal Matrix from QR factorization.*
- std::ostream & operator<< (std::ostream &stream, mtk::UniStgGrid1D &in)
- std::ostream & operator<< (std::ostream &stream, mtk::UniStgGrid2D &in)
- std::ostream & operator<< (std::ostream &stream, mtk::UniStgGrid3D &in)

## Variables

- const float kZero {0.0f}

  *MTK's zero defined according to selective compilation.*
- const float kOne {1.0f}

  *MTK's one defined according to selective compilation.*
- const float kTwo {2.0f}

  *MTK's two defined according to selective compilation.*
- const float kDefaultTolerance {1e-7f}

  *Considered tolerance for comparisons in numerical methods.*
- const int kDefaultOrderAccuracy {2}

  *Default order of accuracy for mimetic operators.*
- const float kDefaultMimeticThreshold {1e-6f}

  *Default tolerance for higher-order mimetic operators.*
- const int kCriticalOrderAccuracyDiv {8}

  *At this order (and higher) we must use the CBSA to construct.*
- const int kCriticalOrderAccuracyGrad {10}

  *At this order (and higher) we must use the CBSA to construct.*

### 15.1.1 Function Documentation

#### 15.1.1.1 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::Interp1D & *in* )

1. Print approximating coefficients for the interior.

Definition at line 66 of file mtk_interp_1d.cc.

#### 15.1.1.2 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::UniStgGrid3D & *in* )

1. Print spatial coordinates.
2. Print scalar field.

Definition at line 67 of file mtk_uni_stg_grid_3d.cc.

#### 15.1.1.3 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::UniStgGrid2D & *in* )

1. Print spatial coordinates.
2. Print scalar field.

Definition at line 67 of file mtk_uni_stg_grid_2d.cc.

#### 15.1.1.4 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::UniStgGrid1D & *in* )

1. Print spatial coordinates.
2. Print scalar field.

Definition at line 68 of file mtk_uni_stg_grid_1d.cc.

#### 15.1.1.5 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::Lap1D & *in* )

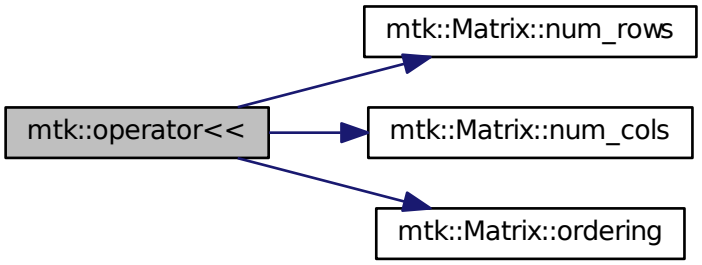
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 73 of file mtk_lap_1d.cc.

#### 15.1.1.6 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::DenseMatrix & *in* )

Definition at line 77 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




#### 15.1.1.7 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::Grad1D & *in* )

1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. Print mimetic weights.
4. Print mimetic approximations at the boundary.

Definition at line 79 of file mtk_grad_1d.cc.

#### 15.1.1.8 std::ostream& mtk::operator<< ( std::ostream & *stream,* mtk::Div1D & *in* )

1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. Print mimetic weights.
4. Print mimetic approximations at the boundary.

Definition at line 79 of file mtk_div_1d.cc.

#### 15.1.1.9 void mtk::saxpy_ ( int * *n,* float * *sa,* float * *sx,* int * *incx,* float * *sy,* int * *incy* )

Here is the caller graph for this function:

#### 15.1.1.10 void mtk::sgels_ ( char * *trans*, int * *m*, int * *n*, int * *nrhs*, Real * *a*, int * *lda*, Real * *b*, int * *ldb*, Real * *work*, int * *lwork*, int * *info* )

SGELS solves overdetermined or underdetermined real linear systems involving an M-by-N matrix A, or its transpose, using a QR or LQ factorization of A. It is assumed that A has full rank.

The following options are provided:

1. If TRANS = 'N' and m >= n: find the least squares solution of an overdetermined system, i.e., solve the least squares problem

```
minimize || B - A*X ||.
```

2. If TRANS = 'N' and m < n: find the minimum norm solution of an underdetermined system A * X = B.
3. If TRANS = 'T' and m >= n: find the minimum norm solution of an undetermined system A**T * X = B.
4. If TRANS = 'T' and m < n: find the least squares solution of an overdetermined system, i.e., solve the least squares problem

```
minimize || B - A**T * X ||.
```

Several right hand side vectors b and solution vectors x can be handled in a single call; they are stored as the columns of the M-by-NRHS right hand side matrix B and the N-by-NRHS solution matrix X.

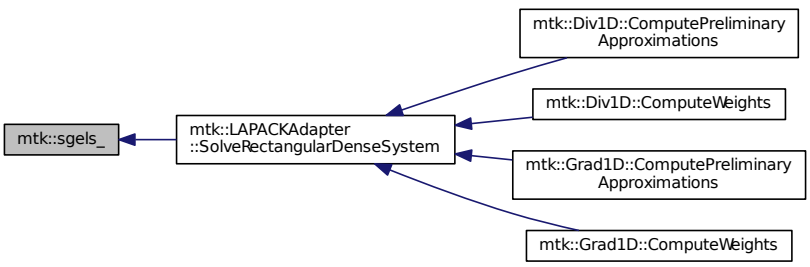
**See also**

http://www.math.utah.edu/software/lapack/lapack-s/sgels.html

**Parameters**

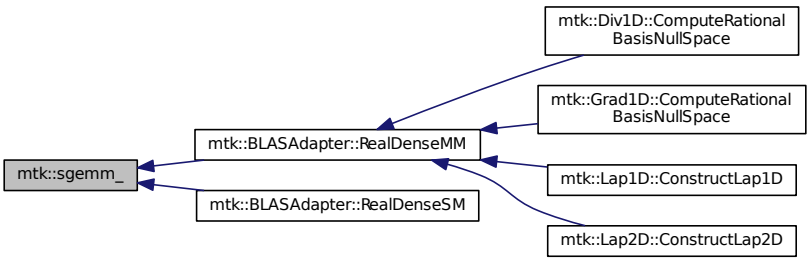
| | | |
|---|---|---|
| in | *trans* | Am I giving the transpose of the matrix? |
| in | *m* | The number of rows of the matrix a. m >= 0. |
| in | *n* | The number of columns of the matrix a. n >= 0. |
| in | *nrhs* | The number of right-hand sides. |
| in,out | *a* | On entry, the m-by-n matrix a. |
| in | *lda* | The leading dimension of a. lda >= max(1,m). |
| in,out | *b* | On entry, matrix b of right-hand side vectors. |
| in | *ldb* | The leading dimension of b. ldb >= max(1,m,n). |
| in,out | *work* | On exit, if info = 0, work(1) is optimal lwork. |
| in,out | *lwork* | The dimension of the array work. |
| in,out | *info* | If info = 0, then successful exit. |

Here is the caller graph for this function:



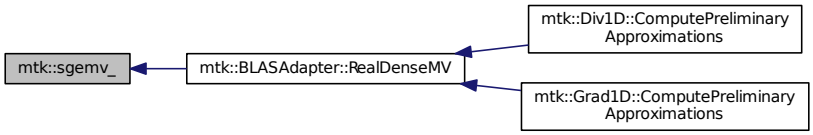
15.1.1.11 void mtk::sgemm_ ( char * *transa*, char * *transb*, int * *m*, int * *n*, int * *k*, double * *alpha*, double * *a*, int * *lda*, double * *b*, aamm int * *ldb*, double * *beta*, double * *c*, int * *ldc* )

Here is the caller graph for this function:




15.1.1.12 void mtk::sgemv_ ( char * *trans*, int * *m*, int * *n*, float * *alpha*, float * *a*, int * *lda*, float * *x*, int * *incx*, float * *beta*, float * *y*, int * *incy* )

Here is the caller graph for this function:




15.1.1.13 void mtk::sgeqrf_ ( int * *m*, int * *n*, Real * *a*, int * *lda*, Real * *tau*, Real * *work*, int * *lwork*, int * *info* )

Single-Precision Orthogonal Make Q from QR: dormqr_ overwrites the general real M-by-N matrix C with (Table 1):

```
SIDE = 'L'      SIDE = 'R'
```

TRANS = 'N': Q * C C * Q TRANS = 'T': Q**T * C C * Q**T

where Q is a real orthogonal matrix defined as the product of k elementary reflectors

```
Q = H(1) H(2) . . . H(k)
```

as returned by SGEQRF. Q is of order M if SIDE = 'L' and of order N if SIDE = 'R'.

**See also**

http://www.netlib.org/lapack/explore-html/df/d97/sgeqrf_8f.html

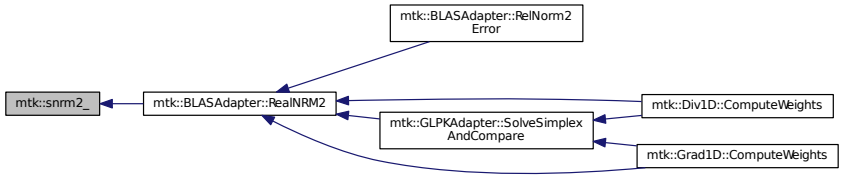
**Parameters**

| | | |
|---|---|---|
| in | *m* | The number of columns of the matrix a. n >= 0. |
| in | *n* | The number of columns of the matrix a. n >= 0. |
| in,out | *a* | On entry, the n-by-n matrix a. |
| in | *lda* | Leading dimension matrix. LDA >= max(1,M). |
| in,out | *tau* | Scalars from elementary reflectors. min(M,N). |
| in,out | *work* | Workspace. info = 0, work(1) is optimal lwork. |
| in | *lwork* | The dimension of work. lwork >= max(1,n). |
| in | *info* | info = 0: successful exit. |

#### 15.1.1.14 void mtk::sgesv_ ( int * *n*, int * *nrhs*, Real * *a*, int * *lda*, int * *ipiv*, Real * *b*, int * *ldb*, int * *info* )

#### 15.1.1.15 float mtk::snrm2_ ( int * *n*, float * *x*, int * *incx* )

Here is the caller graph for this function:




#### 15.1.1.16 void mtk::sormqr_ ( char * *side*, char * *trans*, int * *m*, int * *n*, int * *k*, Real * *a*, int * *lda*, Real * *tau*, Real * *c*, int * *ldc*, Real * *work*, int * *lwork*, int * *info* )

Single-Precision Orthogonal Make Q from QR: sormqr_ overwrites the general real M-by-N matrix C with (Table 1):

```
SIDE = 'L'      SIDE = 'R'
```

TRANS = 'N': Q * C C * Q TRANS = 'T': Q**T * C C * Q**T

where Q is a real orthogonal matrix defined as the product of k elementary reflectors

```
Q = H(1) H(2) . . . H(k)
```

as returned by SGEQRF. Q is of order M if SIDE = 'L' and of order N if SIDE = 'R'.

**See also**

http://www.netlib.org/lapack/explore-html/d0/d98/sormqr_8f_source.html

**Parameters**

| | | |
|---|---|---|
| in | *side* | See Table 1 above. |
| in | *trans* | See Table 1 above. |
| in | *m* | Number of rows of the C matrix. |
| in | *n* | Number of columns of the C matrix. |
| in | *k* | Number of reflectors. |
| in,out | *a* | The matrix containing the reflectors. |
| in | *lda* | The dimension of work. lwork >= max(1,n). |
| in | *tau* | Scalar factors of the elementary reflectors. |
| in | *c* | Output matrix. |
| in | *ldc* | Leading dimension of the output matrix. |
| in,out | *work* | Workspace. info = 0, work(1) optimal lwork. |
| in | *lwork* | The dimension of work. |
| in,out | *info* | info = 0: successful exit. |

# Chapter 16

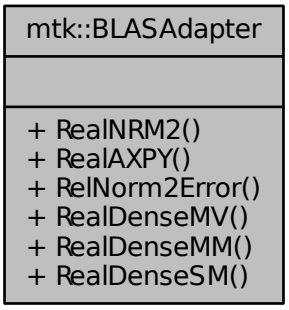
# Class Documentation

## 16.1 mtk::BLASAdapter Class Reference

Adapter class for the BLAS API.

`#include <mtk_blas_adapter.h>`

Collaboration diagram for mtk::BLASAdapter:




### Static Public Member Functions

- static Real RealNRM2 (Real ∗in, int &in_length)

  *Compute the* $||\mathbf{x}||_2$ *of given array* $\mathbf{x}$.
- static void RealAXPY (Real alpha, Real ∗xx, Real ∗yy, int &in_length)

  *Real-Arithmetic Scalar-Vector plus a Vector.*
- static Real RelNorm2Error (Real ∗computed, Real ∗known, int length)

  *Computes the relative norm-2 of the error.*
- static void RealDenseMV (Real &alpha, DenseMatrix &aa, Real ∗xx, Real &beta, Real ∗yy)

  *Real-Arithmetic General (Dense matrices) Matrix-Vector Multiplier.*

- static DenseMatrix RealDenseMM (DenseMatrix &aa, DenseMatrix &bb)

  *Real-Arithmetic General (Dense matrices) Matrix-Matrix multiplier.*

- static DenseMatrix RealDenseSM (Real alpha, DenseMatrix &aa)

  *Real-Arithmetic General (Dense matrices) Scalar-Matrix multiplier.*

### 16.1.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the BLAS.

The **BLAS (Basic Linear Algebra Subprograms)** are routines that provide standard building blocks for performing basic vector and matrix operations. The Level 1 BLAS perform scalar, vector and vector-vector operations, the Level 2 BLAS perform matrix-vector operations, and the Level 3 BLAS perform matrix-matrix operations.

**See also**

http://www.netlib.org/blas/

Definition at line 96 of file mtk_blas_adapter.h.

### 16.1.2 Member Function Documentation

#### 16.1.2.1 void mtk::BLASAdapter::RealAXPY ( mtk::Real *alpha*, mtk::Real * *xx*, mtk::Real * *yy*, int & *in_length* ) [static]

Performs

$$\mathbf{y} := \alpha \mathbf{A} mathbf x + \mathbf{y}$$

**Parameters**

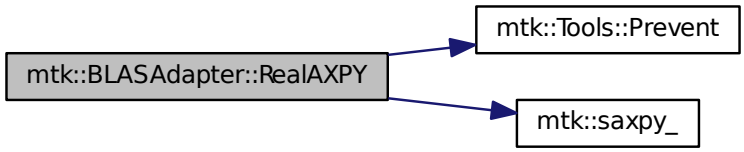
| | | |
|---|---|---|
| in | *alpha* | Scalar of the first array. |
| in | *xx* | First array. |
| in | *yy* | Second array. |
| in | *in_length* | Lengths of the given arrays. |

**Returns**

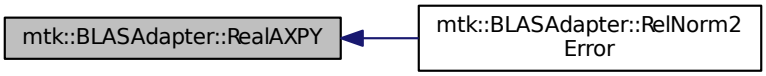
Norm-2 of the given array.

Definition at line 339 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.1.2.2 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM ( mtk::DenseMatrix & *aa*, mtk::DenseMatrix & *bb* ) [static]

Performs:

$$\mathbf{C} := \mathbf{AB}$$

**Parameters**

| | | |
|---|---|---|
| in | *aa* | First matrix. |
| in | *bb* | Second matrix. |

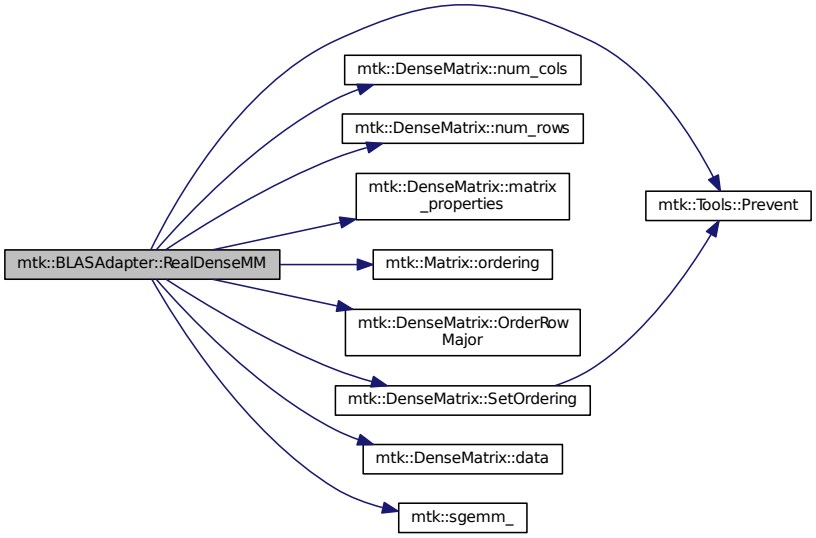
**See also**

http://ejspeiro.github.io/Netlib-and-CPP/

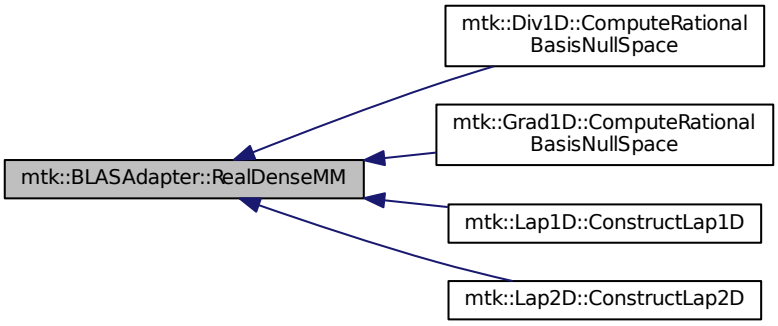
1. Make sure input matrices are row-major ordered.
2. Setup the problem.
3. Perform multiplication.

Definition at line 409 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.1.2.3 void mtk::BLASAdapter::RealDenseMV ( mtk::Real & *alpha*, mtk::DenseMatrix & *aa*, mtk::Real * *xx*, mtk::Real & *beta*, mtk::Real * *yy* ) [static]

Performs

$$\mathbf{y} := \alpha\mathbf{A}\mathbf{x} + \beta\mathbf{y}$$

**Parameters**

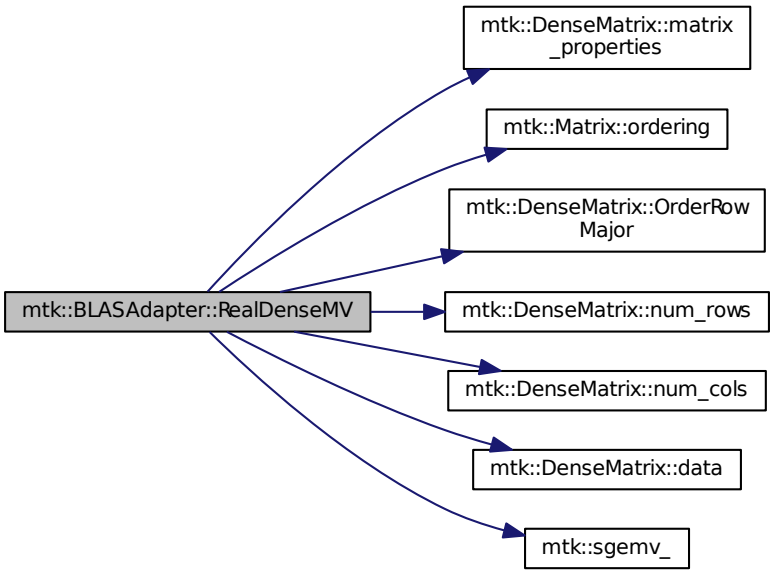
| | | |
|---|---|---|
| in | *alpha* | First scalar. |
| in | *aa* | Given matrix. |
| in | *xx* | First vector. |
| in | *beta* | Second scalar. |
| in,out | *yy* | Second vector (output). |

**See also**

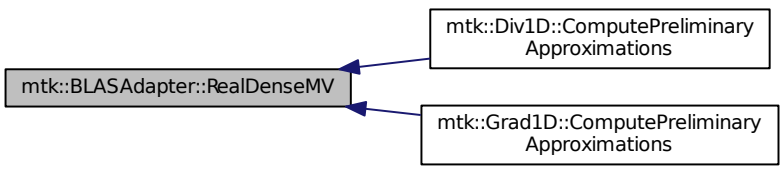
http://ejspeiro.github.io/Netlib-and-CPP/

Definition at line 378 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



#### 16.1.2.4 mtk::DenseMatrix mtk::BLASAdapter::RealDenseSM ( mtk::Real *alpha*, mtk::DenseMatrix & *aa* ) [static]

Performs:

$$\mathbf{B} := \alpha\mathbf{A}$$

**Parameters**

| | | |
|---|---|---|
| in | *alpha* | Input scalar. |
| in | *aa* | Input matrix. |

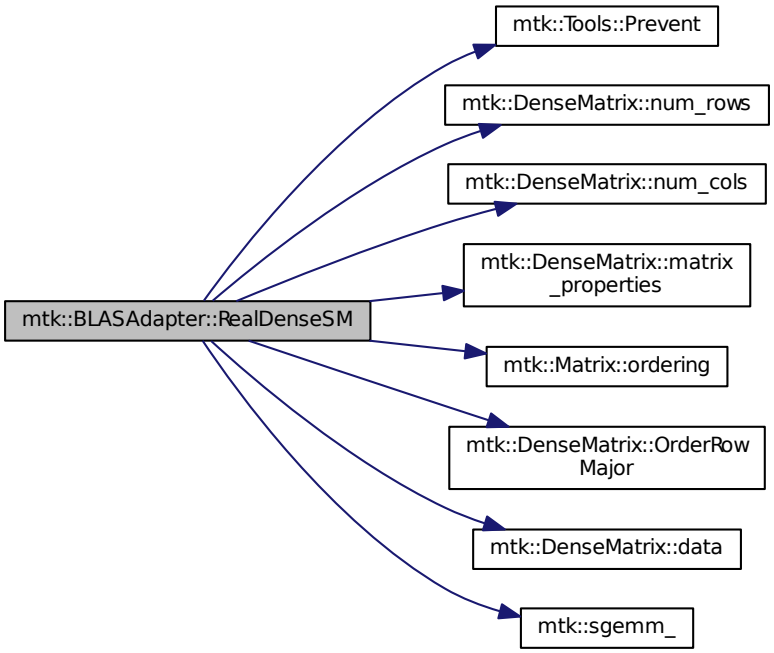
**See also**

http://ejspeiro.github.io/Netlib-and-CPP/

1. Make sure input matrices are row-major ordered.
2. Setup the problem.
3. Perform multiplication.

Definition at line 466 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




#### 16.1.2.5 mtk::Real mtk::BLASAdapter::RealNRM2 ( Real * *in*, int & *in_length* ) [static]

**Parameters**

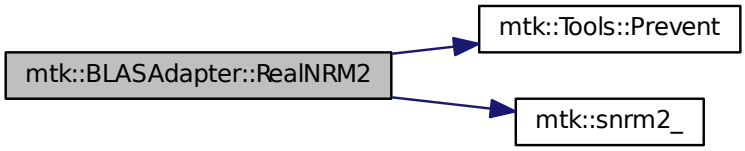
| | | |
|---|---|---|
| in | *in* | Input array. |
| in | *in_length* | Length of the array. |

**Returns**

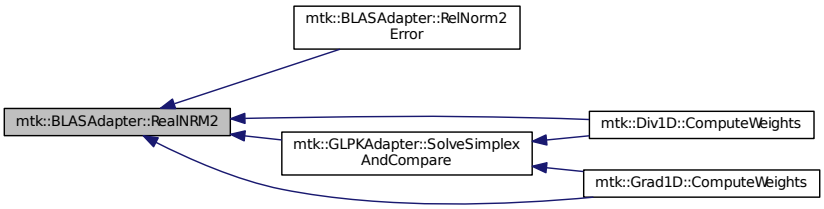
Norm-2 of the given array.

Definition at line 324 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.1.2.6 mtk::Real mtk::BLASAdapter::RelNorm2Error ( mtk::Real * *computed*, mtk::Real * *known*, int *length* ) [static]

We compute

$$\frac{||\tilde{\mathbf{x}} - \mathbf{x}||_2}{||\mathbf{x}||_2}.$$

**Parameters**

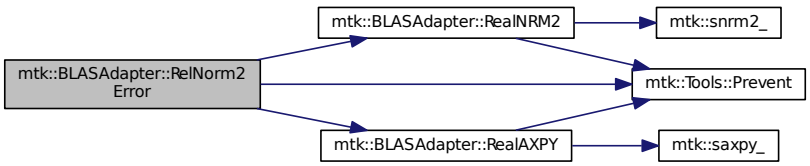
| | | |
|---|---|---|
| in | *known* | Array containing the computed solution. |
| in | *computed* | Array containing the known solution (ref. solution). |

**Returns**

Relative norm-2 of the error, aka, the difference between the arrays.

Definition at line 358 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




The documentation for this class was generated from the following files:

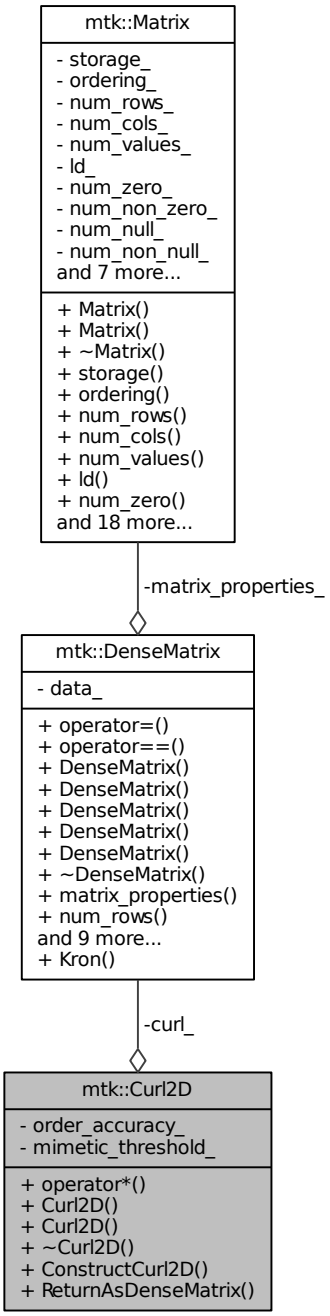
- include/mtk_blas_adapter.h
- src/mtk_blas_adapter.cc

## 16.2 mtk::Curl2D Class Reference

Implements a 2D mimetic curl operator.

`#include <mtk_curl_2d.h>`

Collaboration diagram for mtk::Curl2D:




## Public Member Functions

- UniStgGrid3D operator∗ (const UniStgGrid2D &grid) const

*Operator application operator on a grid.*

- Curl2D ()

  *Default constructor.*

- Curl2D (const Curl2D &curl)

  *Copy constructor.*

- ~Curl2D ()

  *Destructor.*

- bool ConstructCurl2D (const UniStgGrid2D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix curl_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.2.1 Detailed Description

This class implements a 2D curl operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 77 of file mtk_curl_2d.h.

## 16.2.2 Constructor & Destructor Documentation

### 16.2.2.1 mtk::Curl2D::Curl2D ( )

Definition at line 79 of file mtk_curl_2d.cc.

### 16.2.2.2 mtk::Curl2D::Curl2D ( const Curl2D & *curl* )

**Parameters**

| | | |
|---|---|---|
| in | *curl* | Given curl. |

Definition at line 83 of file mtk_curl_2d.cc.

### 16.2.2.3 mtk::Curl2D::~Curl2D ( )

Definition at line 87 of file mtk_curl_2d.cc.

### 16.2.3 Member Function Documentation

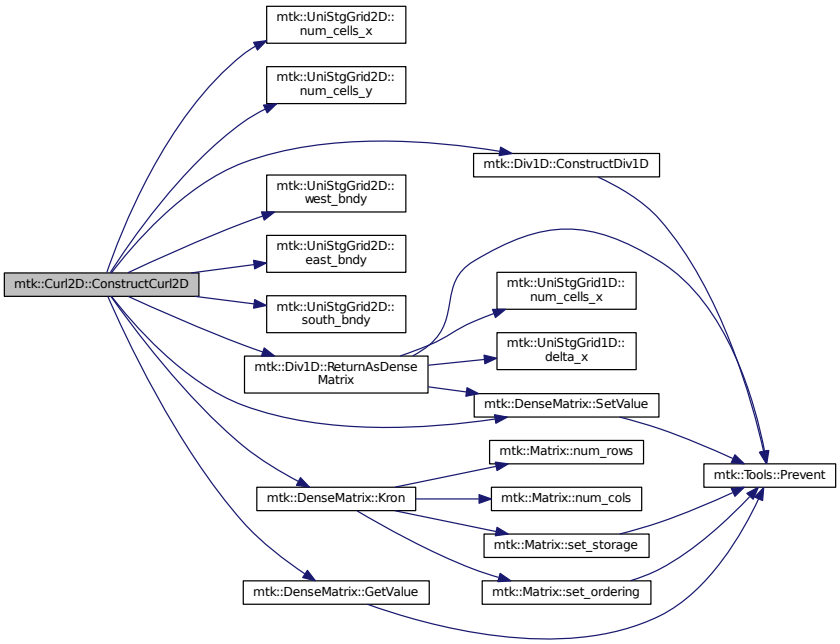
#### 16.2.3.1 bool mtk::Curl2D::ConstructCurl2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

Definition at line 89 of file mtk_curl_2d.cc.

Here is the call graph for this function:




#### 16.2.3.2 mtk::UniStgGrid3D mtk::Curl2D::operator∗ ( const UniStgGrid2D & *grid* ) const

1. Convert given vector field, into the required auxiliary vector field.

Definition at line 70 of file mtk_curl_2d.cc.

#### 16.2.3.3 mtk::DenseMatrix mtk::Curl2D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

Definition at line 157 of file mtk_curl_2d.cc.

### 16.2.4 Member Data Documentation

#### 16.2.4.1 DenseMatrix mtk::Curl2D::curl_ [private]

Definition at line 112 of file mtk_curl_2d.h.

#### 16.2.4.2 Real mtk::Curl2D::mimetic_threshold_ [private]

Definition at line 116 of file mtk_curl_2d.h.

#### 16.2.4.3 int mtk::Curl2D::order_accuracy_ [private]

Definition at line 114 of file mtk_curl_2d.h.

The documentation for this class was generated from the following files:

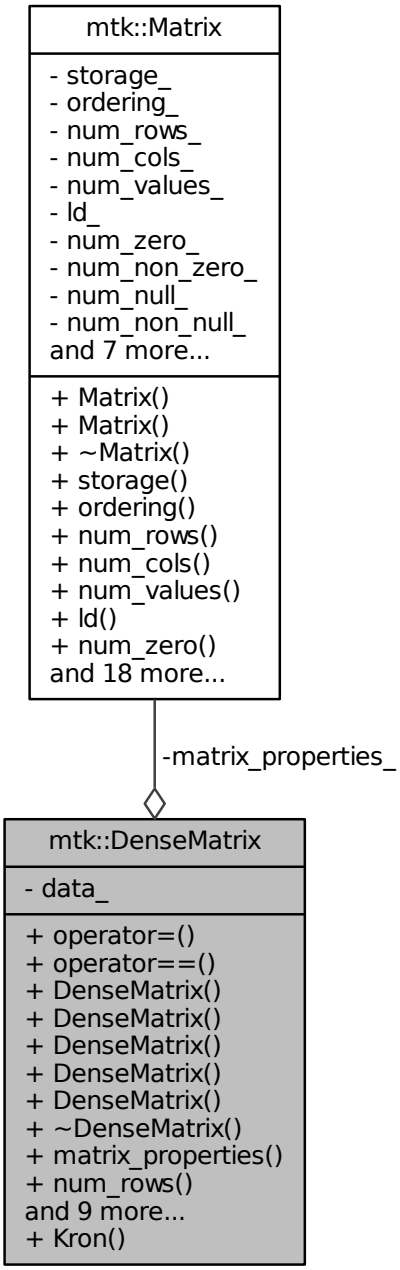
- include/mtk_curl_2d.h
- src/mtk_curl_2d.cc

## 16.3 mtk::DenseMatrix Class Reference

Defines a common dense matrix, using a 1D array.

`#include <mtk_dense_matrix.h>`

Collaboration diagram for mtk::DenseMatrix:




## Public Member Functions

- DenseMatrix & operator= (const DenseMatrix &in)

*Overloaded assignment operator.*

- bool operator== (const DenseMatrix &in)

  *Am I equal to the in matrix?*

- DenseMatrix ()

  *Default constructor.*

- DenseMatrix (const DenseMatrix &in)

  *Copy constructor.*

- DenseMatrix (const int &num_rows, const int &num_cols)

  *Construct a dense matrix based on the given dimensions.*

- DenseMatrix (const int &rank, const bool &padded, const bool &transpose)

  *Construct a zero-rows-padded identity matrix.*

- DenseMatrix (const Real *const gen, const int &gen_length, const int &pro_length, const bool &transpose)

  *Construct a dense Vandermonde matrix.*

- ~DenseMatrix ()

  *Destructor.*

- Matrix matrix_properties () const noexcept

  *Provides access to the matrix data.*

- int num_rows () const noexcept

  *Gets the number of rows.*

- int num_cols () const noexcept

  *Gets the number of columns.*

- Real * data () const noexcept

  *Provides access to the matrix value array.*

- void SetOrdering (mtk::MatrixOrdering oo) noexcept

  *Sets the ordering of the matrix.*

- Real GetValue (const int &row_coord, const int &col_coord) const noexcept

  *Gets a value on the given coordinates.*

- void SetValue (const int &row_coord, const int &col_coord, const Real &val) noexcept

  *Sets a value on the given coordinates.*

- void Transpose ()

  *Transpose this matrix.*

- void OrderRowMajor ()

  *Make the matrix row-wise ordered.*

- void OrderColMajor ()

  *Make the matrix column-wise ordered.*

- bool WriteToFile (const std::string &filename) const

  *Writes matrix to a file compatible with Gnuplot 4.6.*

## Static Public Member Functions

- static DenseMatrix Kron (const DenseMatrix &aa, const DenseMatrix &bb)

  *Construct a dense matrix based on the Kronecker product of arguments.*

### Private Attributes

- Matrix matrix_properties_

  *Data related to the matrix nature.*

- Real * data_

  *Array holding the data in contiguous position in memory.*

### Friends

- std::ostream & operator<< (std::ostream &stream, DenseMatrix &in)

  *Prints the matrix as a block of numbers (standard way).*

## 16.3.1 Detailed Description

For developing purposes, it is better to have a not-so-intrincated data structure implementing matrices. This is the purpose of this class: to be used for prototypes of new code for small test cases. In every other instance, this should be replaced by the most appropriate sparse matrix.

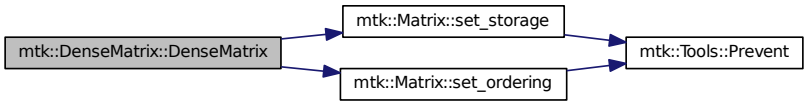
Definition at line 92 of file mtk_dense_matrix.h.

## 16.3.2 Constructor & Destructor Documentation

### 16.3.2.1 mtk::DenseMatrix::DenseMatrix ( )

Definition at line 162 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



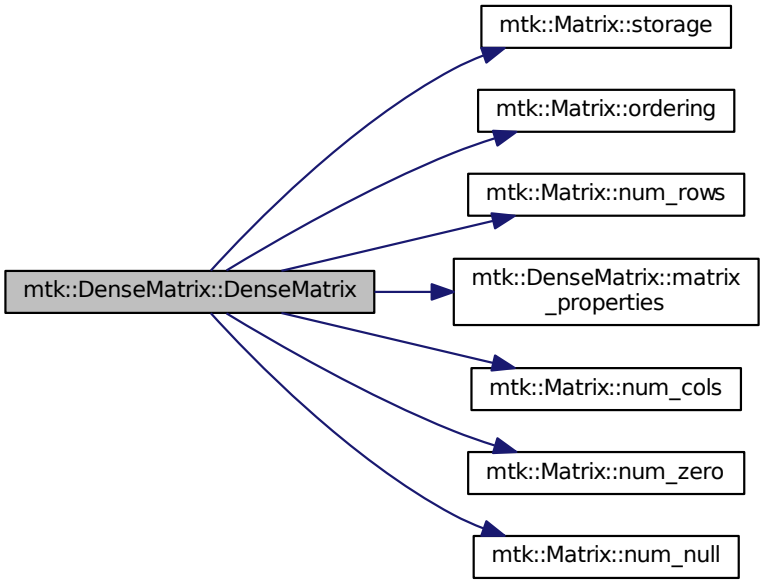

### 16.3.2.2 mtk::DenseMatrix::DenseMatrix ( const DenseMatrix & *in* )

**Parameters**

| | | |
|---|---|---|
| in | *in* | Given matrix. |

Definition at line 168 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




#### 16.3.2.3 mtk::DenseMatrix::DenseMatrix ( const int & *num_rows*, const int & *num_cols* )

**Parameters**

| | | |
|---|---|---|
| in | *num_rows* | Number of rows of the required matrix. |
| in | *num_cols* | Number of rows of the required matrix. |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 201 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

#### 16.3.2.4 mtk::DenseMatrix::DenseMatrix ( const int & *rank*, const bool & *padded*, const bool & *transpose* )

Used in the construction of the mimetic operators.

Def$**$. A **padded matrix** is a matrix with its first and last rows initialized to only zero values:

$$\bar{\mathbf{I}} = \begin{pmatrix} 0 & 0 & 0 & \dots & 0 \\ 1 & 0 & 0 & \dots & 0 \\ 0 & 1 & 0 & \dots & 0 \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & 0 & \dots & 1 \\ 0 & 0 & 0 & \dots & 0 \end{pmatrix}$$

**Parameters**

| | | |
|---|---|---|
| in | *rank* | Rank or number of rows/cols in square matrix. |
| in | *padded* | Should it be padded? |
| in | *transpose* | Should I return the transpose of the requested matrix? |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 223 of file mtk_dense_matrix.cc.

Here is the call graph for this function:


#### 16.3.2.5 mtk::DenseMatrix::DenseMatrix ( const Real *const *gen*, const int & *gen_length*, const int & *pro_length*, const bool & *transpose* )

Def$**$. In linear algebra, a **Vandermonde matrix** is a matrix with terms of a geometric progression in each row. This progression uses the terms of a given **generator vector**:

$$\mathbf{V} = \begin{pmatrix} 1 & \alpha_1 & \alpha_1^2 & \dots & \alpha_1^{n-1} \\ 1 & \alpha_2 & \alpha_2^2 & \dots & \alpha_2^{n-1} \\ 1 & \alpha_3 & \alpha_3^2 & \dots & \alpha_3^{n-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ 1 & \alpha_m & \alpha_m^2 & \dots & \alpha_m^{n-1} \end{pmatrix}$$

This constructor generates a Vandermonde matrix, as defined above.

Obs$**$. It in important to understand that the generator vectors to be used are nothing but a very particular instance of a grid. These are little chunks, little samples, if you will, of a grid which is rectangular and uniform. So the selected samples, on the mtk::Div1D and mtk::Grad1D, basically represent the entire space, the entire grid. This is why nor the CRS nor the CBS algorithms may work for irregular geometries, such as curvilinear grids.

**Parameters**

| | | |
|---|---|---|
| in | *gen* | Given generator vector. |
| in | *gen_length* | Length generator vector. |
| in | *pro_length* | Length the progression. |
| in | *transpose* | Should the transpose be created instead? |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 264 of file mtk_dense_matrix.cc.

Here is the call graph for this function:


#### 16.3.2.6 mtk::DenseMatrix::~DenseMatrix ( )

Definition at line 312 of file mtk_dense_matrix.cc.

### 16.3.3 Member Function Documentation

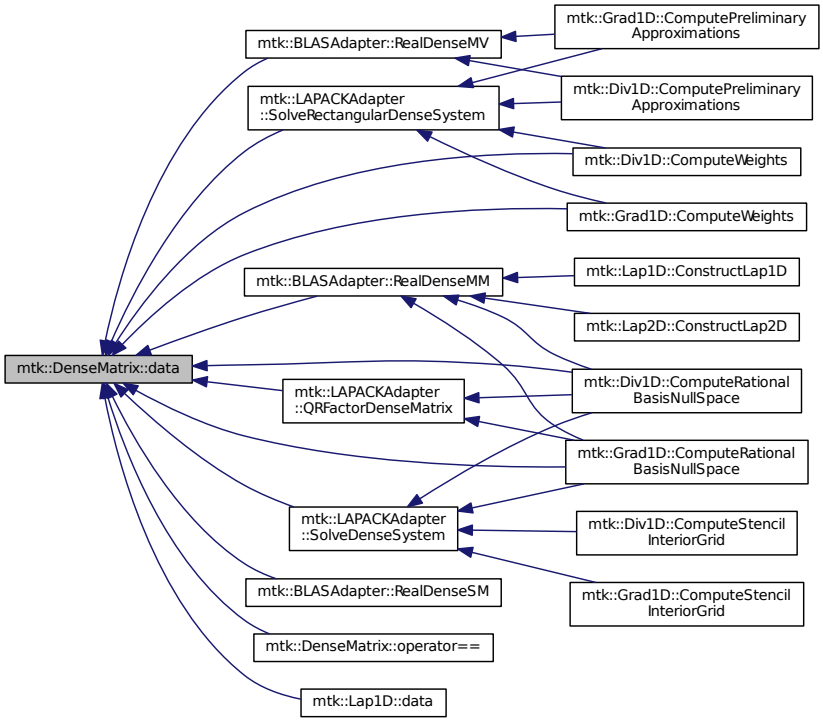
#### 16.3.3.1 mtk::Real * mtk::DenseMatrix::data ( ) const [noexcept]

**Returns**

Pointer to an array of mtk::Real.

Definition at line 343 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:




### 16.3.3.2 mtk::Real mtk::DenseMatrix::GetValue ( const int & *row_coord*, const int & *col_coord* ) const [noexcept]

**Parameters**

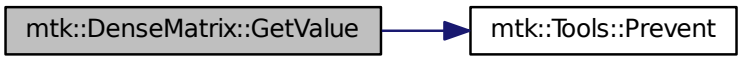
| | | |
|---|---|---|
| in | *row_coord* | Row coordinate. |
| in | *col_coord* | Column coordinate. |

**Returns**

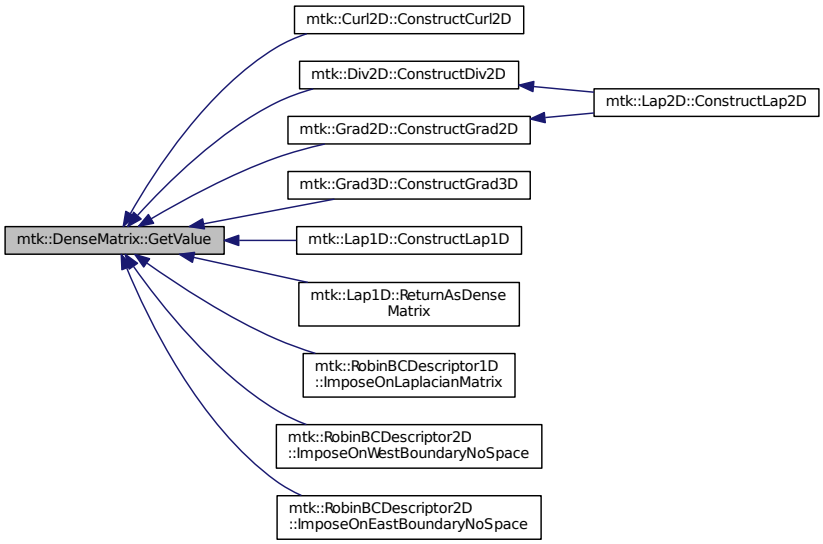
The required value at the specified coordinates.

Definition at line 348 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.3.3.3 mtk::DenseMatrix mtk::DenseMatrix::Kron ( const DenseMatrix & *aa*, const DenseMatrix & *bb* ) [static]

**Parameters**

| | | |
|---|---|---|
| in | *aa* | First matrix. |
| in | *bb* | Second matrix. |

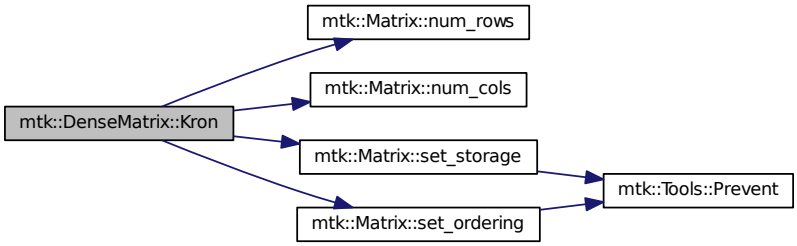
**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

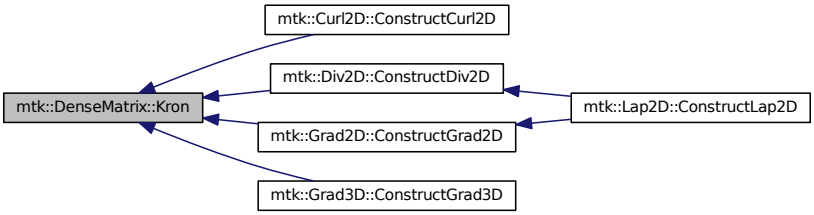
**Todo** Implement Kronecker product using the BLAS.

Definition at line 490 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



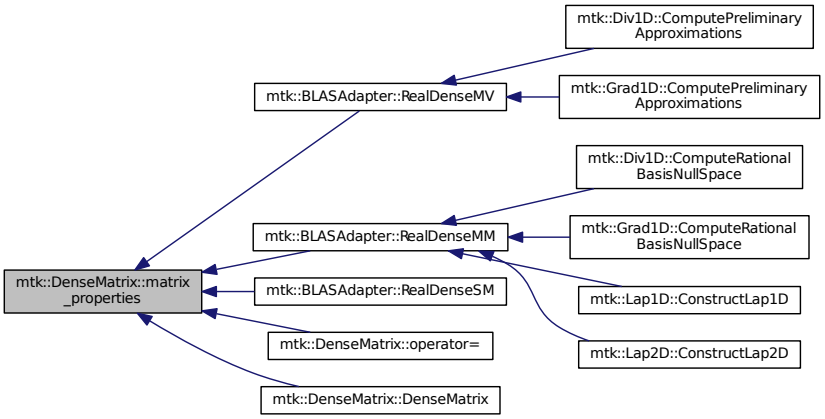

#### 16.3.3.4 mtk::Matrix mtk::DenseMatrix::matrix_properties ( ) const [noexcept]

**Returns**

Pointer to a Matrix.

Definition at line 318 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



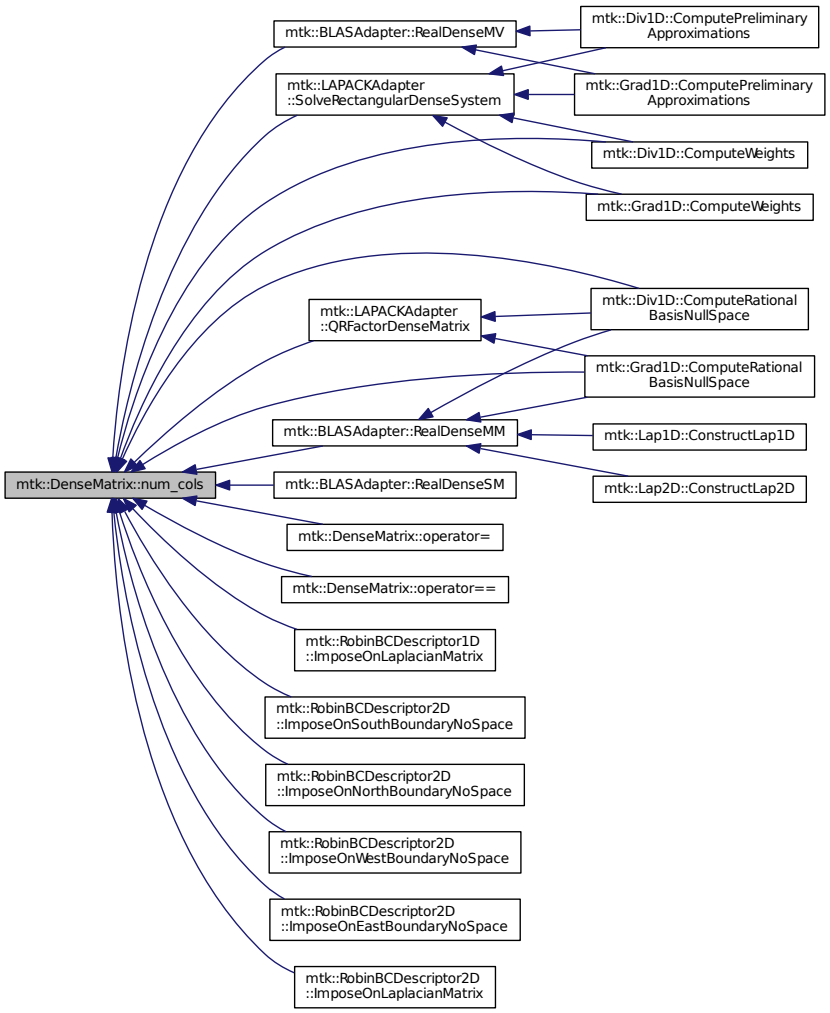

#### 16.3.3.5 int mtk::DenseMatrix::num_cols ( ) const [noexcept]

**Returns**

Number of columns of the matrix.

Definition at line 338 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



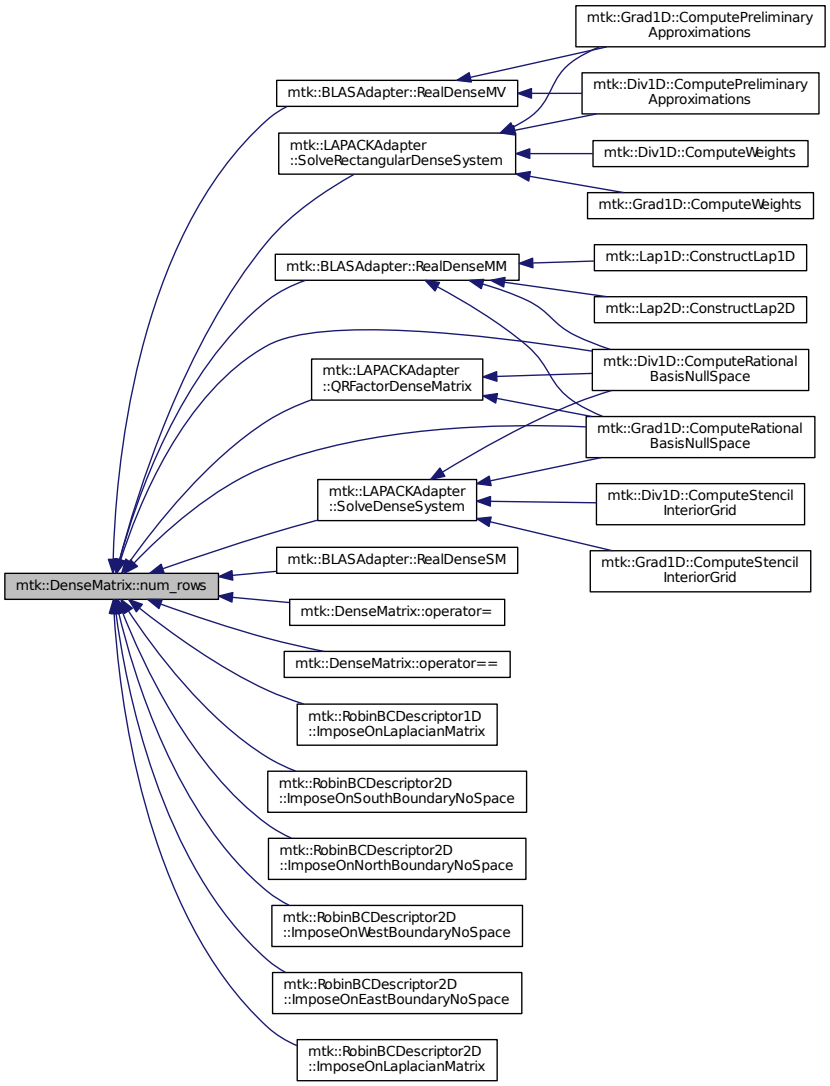

#### 16.3.3.6 int mtk::DenseMatrix::num_rows ( ) const [noexcept]

**Returns**

Number of rows of the matrix.

Definition at line 333 of file mtk_dense_matrix.cc.

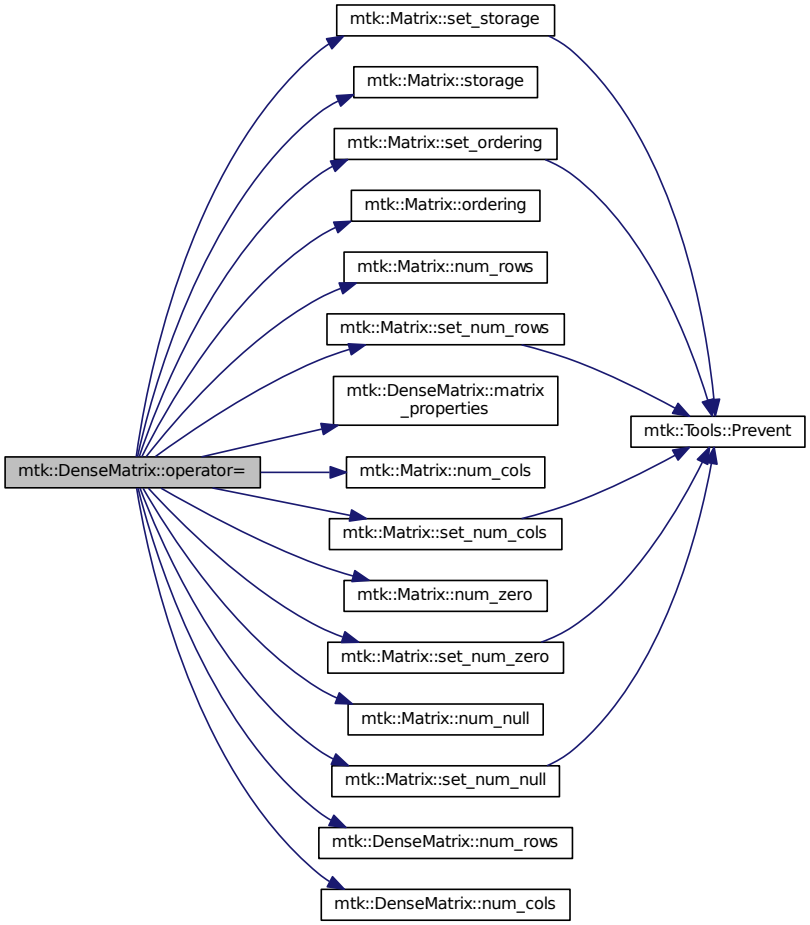
Here is the caller graph for this function:




#### 16.3.3.7 mtk::DenseMatrix & mtk::DenseMatrix::operator= ( const DenseMatrix & *in* )

Definition at line 100 of file mtk_dense_matrix.cc.

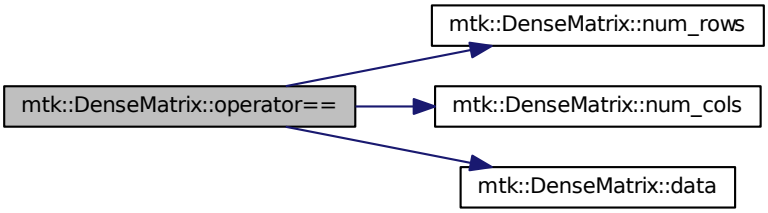
Here is the call graph for this function:




#### 16.3.3.8 bool mtk::DenseMatrix::operator== ( const DenseMatrix & *in* )

Definition at line 141 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

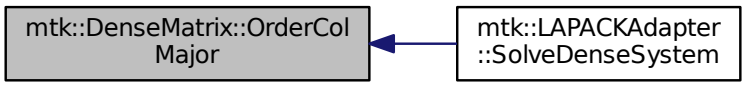



#### 16.3.3.9 void mtk::DenseMatrix::OrderColMajor ( )

**Todo** Improve this so that no new arrays have to be created.

Definition at line 451 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:

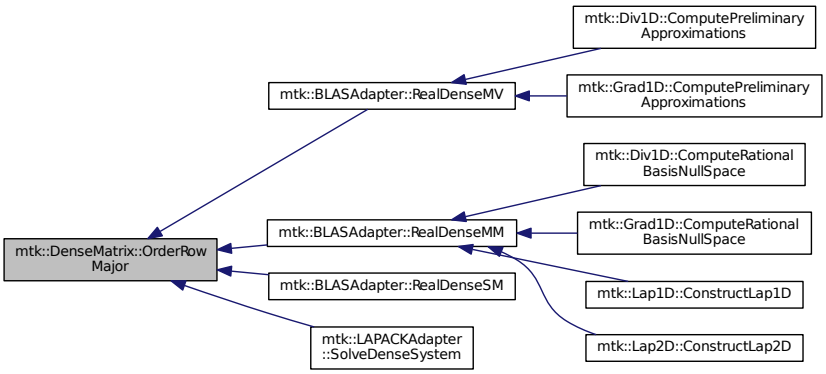



#### 16.3.3.10 void mtk::DenseMatrix::OrderRowMajor ( )

**Todo** Improve this so that no new arrays have to be created.

Definition at line 410 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:




#### 16.3.3.11 void mtk::DenseMatrix::SetOrdering ( mtk::MatrixOrdering *oo* ) [noexcept]

**Parameters**

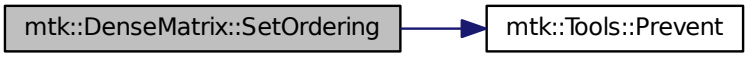
| | | |
|---|---|---|
| in | *oo* | Ordering. |

**Returns**

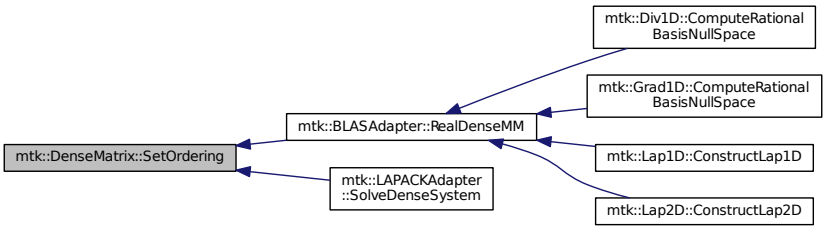
The required value at the specified coordinates.

Definition at line 323 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



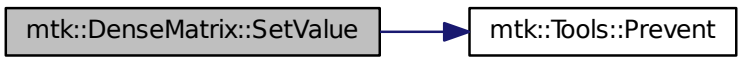

#### 16.3.3.12 void mtk::DenseMatrix::SetValue ( const int & *row_coord,* const int & *col_coord,* const **Real** & *val* ) [noexcept]

**Parameters**

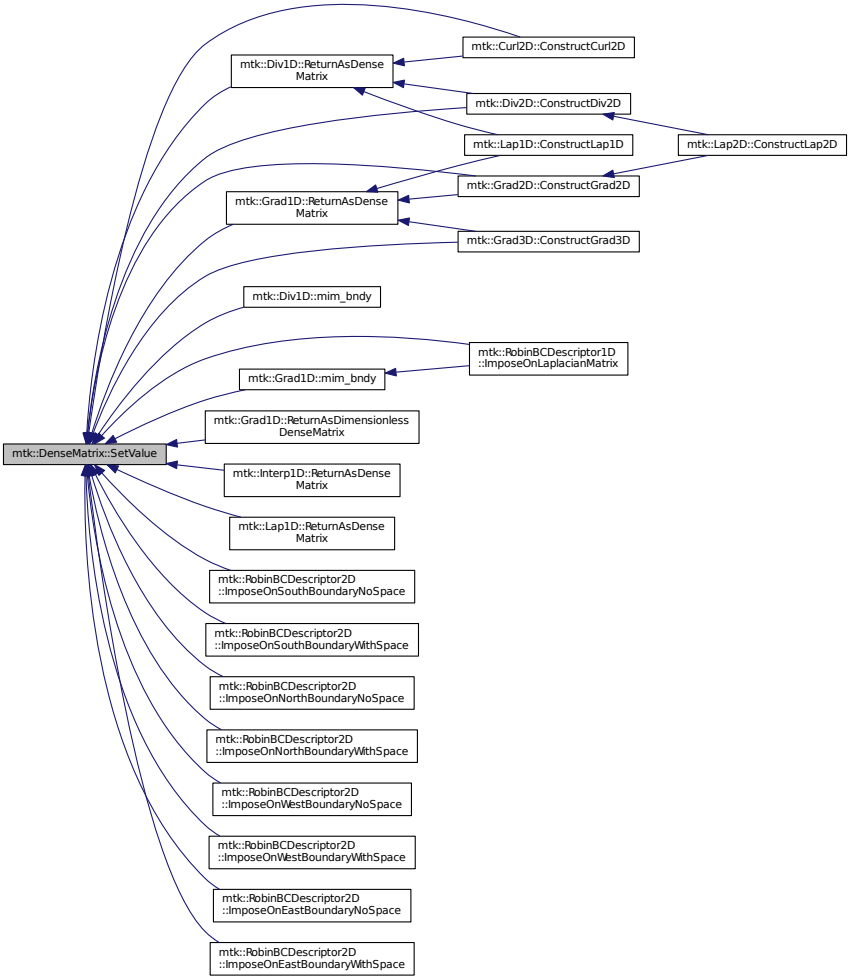
| | | |
|---|---|---|
| in | *row_coord* | Row coordinate. |
| in | *col_coord* | Column coordinate. |
| in | *val* | Row Actual value to be inserted. |

Definition at line 360 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

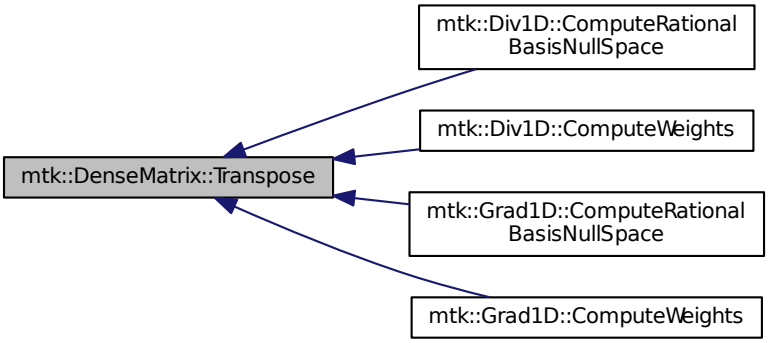



#### 16.3.3.13 void mtk::DenseMatrix::Transpose ( )

**Todo** Improve this so that no extra arrays have to be created.

Definition at line 373 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:




#### 16.3.3.14 bool mtk::DenseMatrix::WriteToFile ( const std::string & *filename* ) const

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Definition at line 531 of file mtk_dense_matrix.cc.

### 16.3.4 Friends And Related Function Documentation

#### 16.3.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::DenseMatrix & *in* ) [friend]

Definition at line 77 of file mtk_dense_matrix.cc.

### 16.3.5 Member Data Documentation

#### 16.3.5.1 Real* mtk::DenseMatrix::data_ [private]

Definition at line 285 of file mtk_dense_matrix.h.

#### 16.3.5.2 Matrix mtk::DenseMatrix::matrix_properties_ [private]

Definition at line 283 of file mtk_dense_matrix.h.

The documentation for this class was generated from the following files:

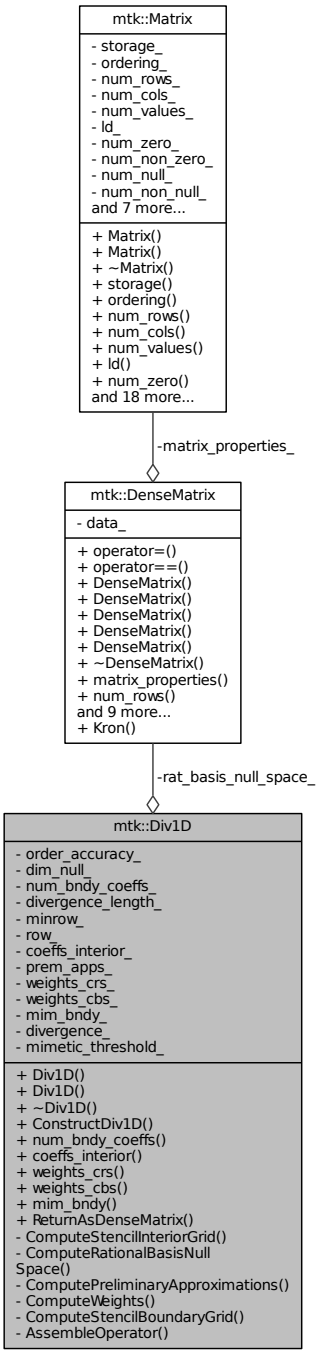
- include/mtk_dense_matrix.h
- src/mtk_dense_matrix.cc

## 16.4 mtk::Div1D Class Reference

Implements a 1D mimetic divergence operator.

`#include <mtk_div_1d.h>`

Collaboration diagram for mtk::Div1D:




## Public Member Functions

- Div1D ()

*Default constructor.*

- Div1D (const Div1D &div)

  *Copy constructor.*

- ~Div1D ()

  *Destructor.*

- bool ConstructDiv1D (int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- int num_bndy_coeffs () const

  *Returns how many coefficients are approximating at the boundary.*

- Real * coeffs_interior () const

  *Returns coefficients for the interior of the grid.*

- Real * weights_crs (void) const

  *Return collection of weights as computed by the CRSA.*

- Real * weights_cbs (void) const

  *Return collection of weights as computed by the CBSA.*

- DenseMatrix mim_bndy () const

  *Return collection of mimetic approximations at the boundary.*

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  *Return the operator as a dense matrix.*

## Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  *Stage 1 of the CBS Algorithm.*

- bool ComputeRationalBasisNullSpace (void)

  *Stage 2.1 of the CBS Algorithm.*

- bool ComputePreliminaryApproximations (void)

  *Stage 2.2 of the CBS Algorithm.*

- bool ComputeWeights (void)

  *Stage 2.3 of the CBS Algorithm.*

- bool ComputeStencilBoundaryGrid (void)

  *Stage 2.4 of the CBS Algorithm.*

- bool AssembleOperator (void)

  *Stage 3 of the CBS Algorithm.*

## Private Attributes

- int order_accuracy_

  *Order of numerical accuracy of the operator.*

- int dim_null_

  *Dim. null-space for boundary approximations.*

- int num_bndy_coeffs_

  *Req. coeffs. per bndy pt. uni. order accuracy.*

- int divergence_length_

  *Length of the output array.*

- int minrow_

*Row from the optimizer with the minimum rel. nor.*

- int row_

  *Row currently processed by the optimizer.*
- DenseMatrix rat_basis_null_space_

  *Rational b. null-space w. bndy.*
- Real * coeffs_interior_

  *Interior stencil.*
- Real * prem_apps_

  *2D array of boundary preliminary approximations.*
- Real * weights_crs_

  *Array containing weights from CRSA.*
- Real * weights_cbs_

  *Array containing weights from CBSA.*
- Real * mim_bndy_

  *Array containing mimetic boundary approximations.*
- Real * divergence_

  *Output array containing the operator and weights.*
- Real mimetic_threshold_

  *< Mimetic threshold.*

## Friends

- std::ostream & operator<< (std::ostream &stream, Div1D &in)

  *Output stream operator for printing.*

### 16.4.1 Detailed Description

This class implements a 1D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 81 of file mtk_div_1d.h.

### 16.4.2 Constructor & Destructor Documentation

#### 16.4.2.1 mtk::Div1D::Div1D ( )

Definition at line 125 of file mtk_div_1d.cc.

#### 16.4.2.2 mtk::Div1D::Div1D ( const Div1D & *div* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

Definition at line 140 of file mtk_div_1d.cc.

#### 16.4.2.3 mtk::Div1D::~Div1D ( )

Definition at line 155 of file mtk_div_1d.cc.

### 16.4.3 Member Function Documentation

#### 16.4.3.1 bool mtk::Div1D::AssembleOperator ( void ) [private]

Construct the output array with the operator and its weights.

1. The first entry of the array will contain the order of accuracy.
2. The second entry the collection of coefficients for interior of grid.
3. If order_accuracy_ $>$ 2, then third entry is the collection of weights.
4. If order_accuracy_ $>$ 2, next dim_null_ entries is approximating coefficients for the west boundary of the grid.

Definition at line 1342 of file mtk_div_1d.cc.

#### 16.4.3.2 mtk::Real * mtk::Div1D::coeffs_interior ( ) const

**Returns**

Coefficients for the interior of the grid.

Definition at line 320 of file mtk_div_1d.cc.

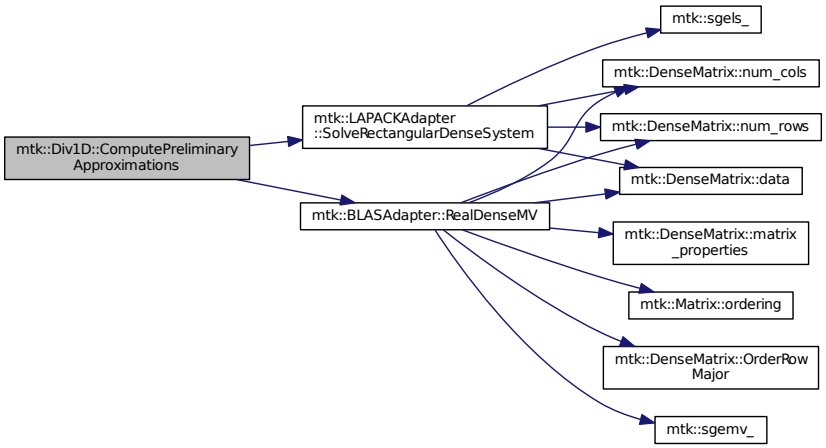
#### 16.4.3.3 bool mtk::Div1D::ComputePreliminaryApproximations ( void ) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the dim_null near-the-boundary columns of the pi matrix.
3. Create the Vandermonde matrix for this iteration.
4. New order-selector vector (gets re-written with LAPACK solutions).
5. Solving TT*rr = ob yields the columns rr of the KK matrix.
6. Scale the KK matrix to make it a rational basis for null-space.
7. Extract the last dim_null values of the pre-scaled ob.
8. Once we posses the bottom elements, we proceed with the scaling.

Definition at line 691 of file mtk_div_1d.cc.

Here is the call graph for this function:




#### 16.4.3.4 bool mtk::Div1D::ComputeRationalBasisNullSpace ( void ) [private]

Compute a rational basis for the null-space of the Vandermonde matrix approximating at the west boundary.

1. Create generator vector for the first approximation.

2. Create Vandermonde matrix.

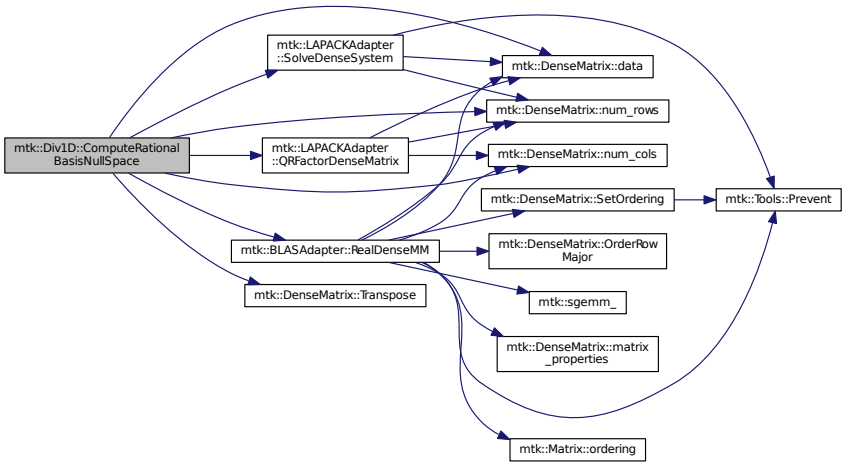
3. QR-factorize the Vandermonde matrix.

4. Extract the basis for the null-space from Q matrix.

5. Scale null-space to make it rational.

Definition at line 515 of file mtk_div_1d.cc.

Here is the call graph for this function:




#### 16.4.3.5 bool mtk::Div1D::ComputeStencilBoundaryGrid ( void ) [private]

Compute mimetic stencil approximating at boundary.

1. Collect lambda values.
2. Compute alpha values.
3. Compute the mimetic boundary approximations.

Definition at line 1241 of file mtk_div_1d.cc.

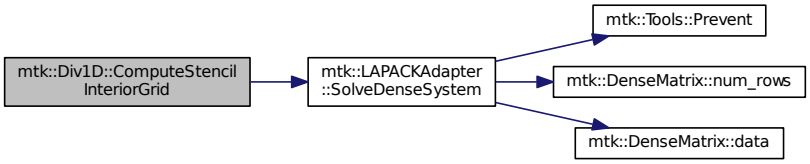
#### 16.4.3.6 bool mtk::Div1D::ComputeStencilInteriorGrid ( void ) [private]

Compute the stencil approximating the interior of the staggered grid.

1. Create vector for interior spatial coordinates.
2. Create Vandermonde matrix (using interior coordinates as generator).
3. Create order-selector vector.
4. Solve dense Vandermonde system to attain the interior coefficients.

Definition at line 414 of file mtk_div_1d.cc.

Here is the call graph for this function:



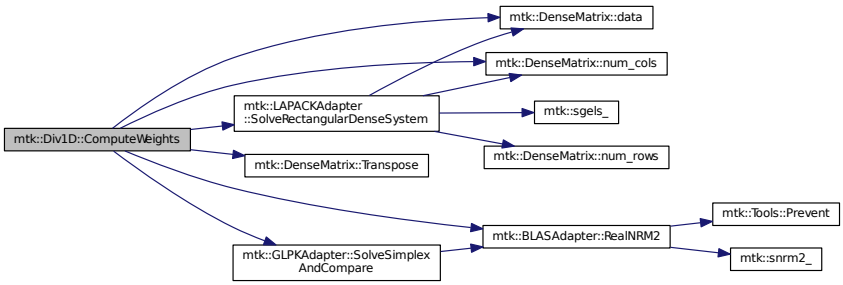

#### 16.4.3.7 bool mtk::Div1D::ComputeWeights ( void ) [private]

Compute the set of mimetic weights to impose the mimetic condition.

1. Construct the ■ matrix.
2. Use interior stencil to build proper RHS vector $\mathbf{h}$.
3. Get weights (as **CRSA**): $\blacksquare\mathbf{q} = \mathbf{h}$.
4. If required order is greater than critical order, start the **CBSA**.
5. Create ■ matrix from ■.
6. Prepare constraint vector as in the CBSA: ■.
7. Brute force search through all the rows of the $\Phi$ matrix.
8. Apply solution found from brute force search.

Definition at line 911 of file mtk_div_1d.cc.

Here is the call graph for this function:



#### 16.4.3.8 bool mtk::Div1D::ConstructDiv1D ( int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

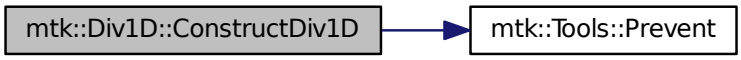
**Returns**

Success of the construction.

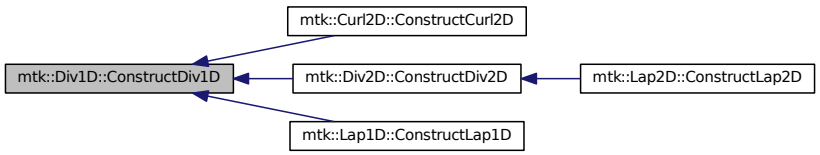
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.
6. Assemble operator.

Definition at line 176 of file mtk_div_1d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



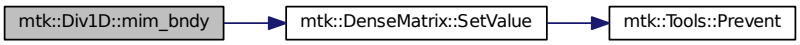

#### 16.4.3.9 mtk::DenseMatrix mtk::Div1D::mim_bndy ( ) const

**Returns**

Collection of mimetic approximations at the boundary.

Definition at line 335 of file mtk_div_1d.cc.

Here is the call graph for this function:




#### 16.4.3.10 int mtk::Div1D::num_bndy_coeffs ( ) const

**Returns**

How many coefficients are approximating at the boundary.

Definition at line 315 of file mtk_div_1d.cc.

#### 16.4.3.11 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix ( const UniStgGrid1D & *grid* ) const

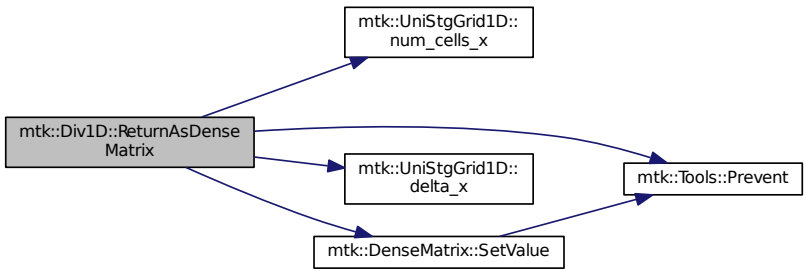
**Returns**

The operator as a dense matrix.

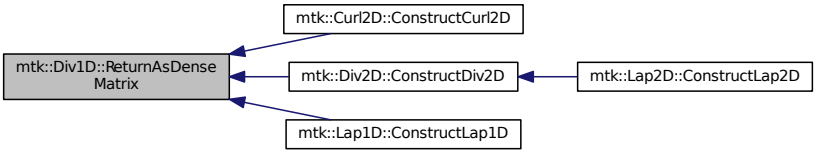
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 350 of file mtk_div_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:




#### 16.4.3.12 mtk::Real * mtk::Div1D::weights_cbs ( void ) const

**Returns**

Collection of weights as computed by the CBSA.

Definition at line 330 of file mtk_div_1d.cc.

#### 16.4.3.13 mtk::Real * mtk::Div1D::weights_crs ( void ) const

**Returns**

Collection of weights as computed by the CRSA.

Definition at line 325 of file mtk_div_1d.cc.

### 16.4.4 Friends And Related Function Documentation

#### 16.4.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::Div1D & *in* ) [friend]

1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. Print mimetic weights.
4. Print mimetic approximations at the boundary.

Definition at line 79 of file mtk_div_1d.cc.

### 16.4.5 Member Data Documentation

#### 16.4.5.1 Real* mtk::Div1D::coeffs_interior_ [private]

Definition at line 202 of file mtk_div_1d.h.

#### 16.4.5.2 int mtk::Div1D::dim_null_ [private]

Definition at line 194 of file mtk_div_1d.h.

#### 16.4.5.3 Real* mtk::Div1D::divergence_ [private]

Definition at line 207 of file mtk_div_1d.h.

#### 16.4.5.4 int mtk::Div1D::divergence_length_ [private]

Definition at line 196 of file mtk_div_1d.h.

#### 16.4.5.5 Real* mtk::Div1D::mim_bndy_ [private]

Definition at line 206 of file mtk_div_1d.h.

#### 16.4.5.6 Real mtk::Div1D::mimetic_threshold_ [private]

Definition at line 209 of file mtk_div_1d.h.

#### 16.4.5.7 int mtk::Div1D::minrow_ [private]

Definition at line 197 of file mtk_div_1d.h.

#### 16.4.5.8 int mtk::Div1D::num_bndy_coeffs_ [private]

Definition at line 195 of file mtk_div_1d.h.

#### 16.4.5.9 int mtk::Div1D::order_accuracy_ [private]

Definition at line 193 of file mtk_div_1d.h.

#### 16.4.5.10 Real* mtk::Div1D::prem_apps_ [private]

Definition at line 203 of file mtk_div_1d.h.

#### 16.4.5.11 DenseMatrix mtk::Div1D::rat_basis_null_space_ [private]

Definition at line 200 of file mtk_div_1d.h.

#### 16.4.5.12 int mtk::Div1D::row_ [private]

Definition at line 198 of file mtk_div_1d.h.

#### 16.4.5.13 Real* mtk::Div1D::weights_cbs_ [private]

Definition at line 205 of file mtk_div_1d.h.

#### 16.4.5.14 Real* mtk::Div1D::weights_crs_ [private]

Definition at line 204 of file mtk_div_1d.h.

The documentation for this class was generated from the following files:

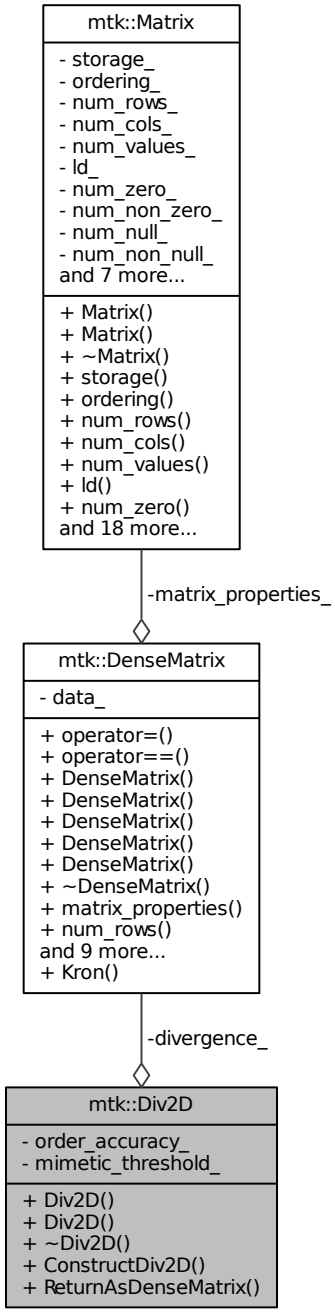
- include/mtk_div_1d.h
- src/mtk_div_1d.cc

## 16.5 mtk::Div2D Class Reference

Implements a 2D mimetic divergence operator.

`#include <mtk_div_2d.h>`

Collaboration diagram for mtk::Div2D:




## Public Member Functions

- Div2D ()

*Default constructor.*

- Div2D (const Div2D &div)

  *Copy constructor.*

- ~Div2D ()

  *Destructor.*

- bool ConstructDiv2D (const UniStgGrid2D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix divergence_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.5.1 Detailed Description

This class implements a 2D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_div_2d.h.

## 16.5.2 Constructor & Destructor Documentation

### 16.5.2.1 mtk::Div2D::Div2D ( )

Definition at line 69 of file mtk_div_2d.cc.

### 16.5.2.2 mtk::Div2D::Div2D ( const Div2D & *div* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

Definition at line 73 of file mtk_div_2d.cc.

### 16.5.2.3 mtk::Div2D::~Div2D ( )

Definition at line 77 of file mtk_div_2d.cc.

### 16.5.3 Member Function Documentation

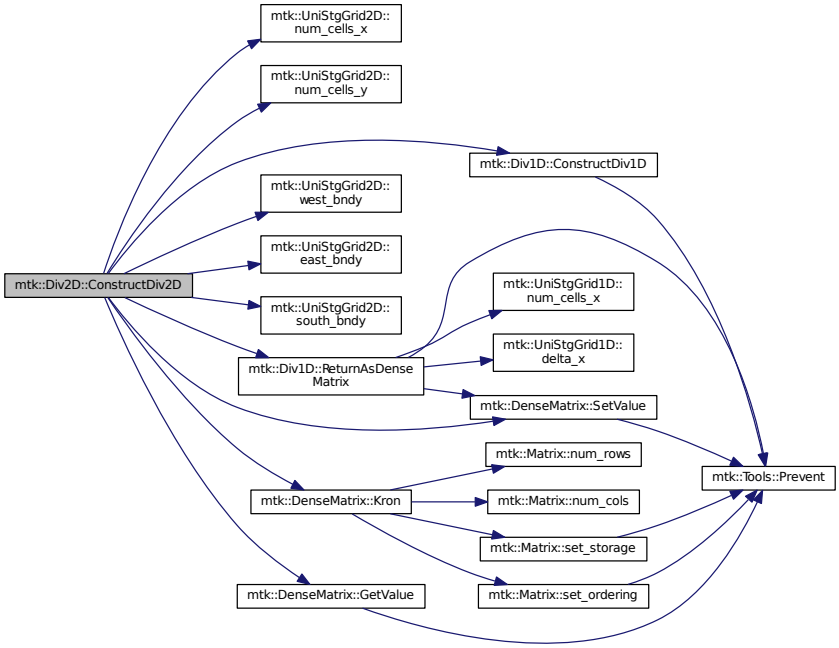
#### 16.5.3.1 bool mtk::Div2D::ConstructDiv2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

Definition at line 79 of file mtk_div_2d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:

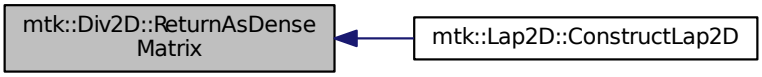

#### 16.5.3.2 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

Definition at line 147 of file mtk_div_2d.cc.

Here is the caller graph for this function:




### 16.5.4 Member Data Documentation

#### 16.5.4.1 DenseMatrix mtk::Div2D::divergence_ [private]

Definition at line 108 of file mtk_div_2d.h.

#### 16.5.4.2 Real mtk::Div2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_div_2d.h.

#### 16.5.4.3 int mtk::Div2D::order_accuracy_ [private]

Definition at line 110 of file mtk_div_2d.h.

The documentation for this class was generated from the following files:

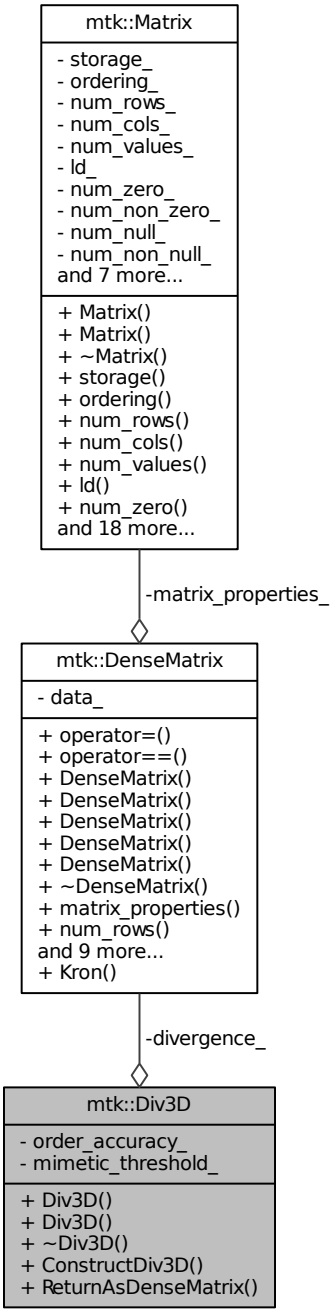
- include/mtk_div_2d.h
- src/mtk_div_2d.cc

## 16.6 mtk::Div3D Class Reference

Implements a 3D mimetic divergence operator.

`#include <mtk_div_3d.h>`

Collaboration diagram for mtk::Div3D:




## Public Member Functions

- Div3D ()

*Default constructor.*

- Div3D (const Div3D &div)

  *Copy constructor.*

- ~Div3D ()

  *Destructor.*

- bool ConstructDiv3D (const UniStgGrid3D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix divergence_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.6.1 Detailed Description

This class implements a 3D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_div_3d.h.

## 16.6.2 Constructor & Destructor Documentation

### 16.6.2.1 mtk::Div3D::Div3D ( )

### 16.6.2.2 mtk::Div3D::Div3D ( const Div3D & *div* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

### 16.6.2.3 mtk::Div3D::~Div3D ( )

## 16.6.3 Member Function Documentation

### 16.6.3.1 bool mtk::Div3D::ConstructDiv3D ( const UniStgGrid3D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

#### 16.6.3.2 DenseMatrix mtk::Div3D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

### 16.6.4 Member Data Documentation

#### 16.6.4.1 DenseMatrix mtk::Div3D::divergence_ [private]

Definition at line 108 of file mtk_div_3d.h.

#### 16.6.4.2 Real mtk::Div3D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_div_3d.h.

#### 16.6.4.3 int mtk::Div3D::order_accuracy_ [private]

Definition at line 110 of file mtk_div_3d.h.

The documentation for this class was generated from the following file:

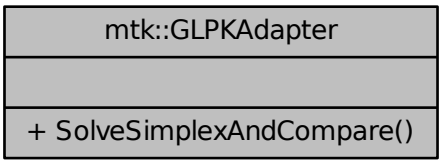
- include/mtk_div_3d.h

## 16.7 mtk::GLPKAdapter Class Reference

Adapter class for the GLPK API.

`#include <mtk_glpk_adapter.h>`

Collaboration diagram for mtk::GLPKAdapter:




### Static Public Member Functions

- static mtk::Real SolveSimplexAndCompare (mtk::Real *A, int nrows, int ncols, int kk, mtk::Real *hh, mtk::Real *qq, int robjective, mtk::Real mimetic_tol, int copy)

  *Solves a CLO problem and compares the solution to a reference solution.*

### 16.7.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the GLPK.

The **GLPK (GNU Linear Programming Kit)** package is intended for solving large-scale linear programming (LP), mixed integer programming (MIP), and other related problems. It is a set of routines written in ANSI C and organized in the form of a callable library.

**Warning**

We use the GLPK temporarily in order to test the CBSA, but it will be removed due to potential licensing issues.

**See also**

http://www.gnu.org/software/glpk/

**Todo** Rescind from the GLPK as the numerical core for CLO problems.

Definition at line 101 of file mtk_glpk_adapter.h.

### 16.7.2 Member Function Documentation

#### 16.7.2.1 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare ( mtk::Real * *A*, int *nrows*, int *ncols*, int *kk*, mtk::Real * *hh*, mtk::Real * *qq*, int *robjective*, mtk::Real *mimetic_tol*, int *copy* ) [static]

This routine is the pivot of the CBSA. It solves a Constrained Linear Optimization (CLO) problem, and it compares the attained solution to a given reference solution. This comparison is done computing the norm-2 relative error.

**Parameters**

| | | |
|---|---|---|
| in | *alpha* | First scalar. |
| in | *AA* | Given matrix. |
| in | *xx* | First vector. |
| in | *beta* | Second scalar. |
| in | *beta* | Second scalar. |
| in,out | *yy* | Second vector (output). |
| in | *xx* | First vector. |
| in | *beta* | Second scalar. |
| in | *beta* | Second scalar. |

**Returns**

Relative error computed between attained solution and provided ref.

**Warning**

GLPK indexes in [1,n], so we must get the extra space needed.

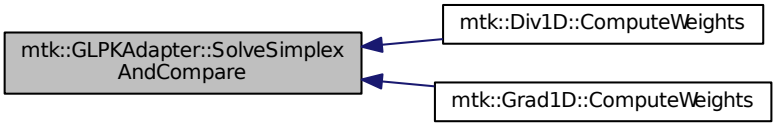
1. Memory allocation.
2. Fill the problem.
3. Copy the row to the vector objective.

4. Forming the RHS.
5. Setting up the objective function.
6. Setting up constraints.
7. Copy the matrix minus the row objective to the glpk problem.
8. Solve problem.

Definition at line 76 of file mtk_glpk_adapter.cc.

Here is the call graph for this function:


Here is the caller graph for this function:




The documentation for this class was generated from the following files:

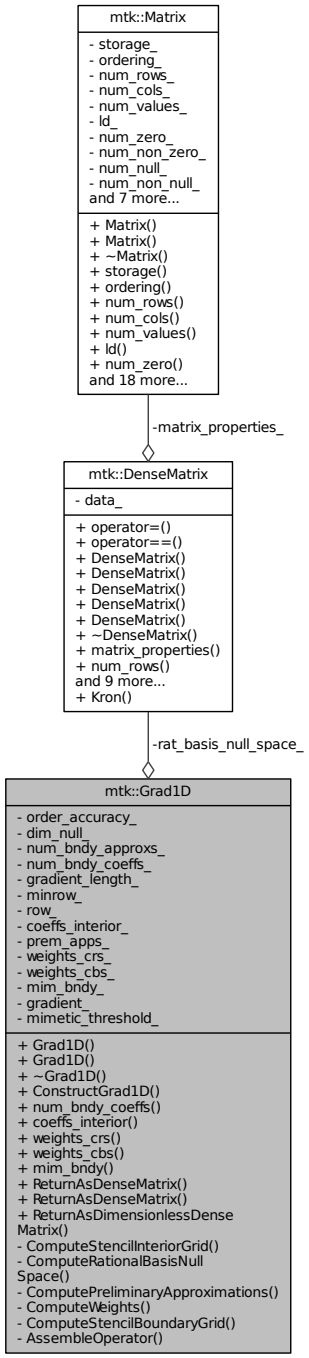
- include/mtk_glpk_adapter.h
- src/mtk_glpk_adapter.cc

## 16.8 mtk::Grad1D Class Reference

Implements a 1D mimetic gradient operator.

`#include <mtk_grad_1d.h>`

Collaboration diagram for mtk::Grad1D:




## Public Member Functions

- Grad1D ()

*Default constructor.*

- Grad1D (const Grad1D &grad)

  *Copy constructor.*

- ~Grad1D ()

  *Destructor.*

- bool ConstructGrad1D (int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimetic↩ Threshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- int num_bndy_coeffs () const

  *Returns how many coefficients are approximating at the boundary.*

- Real * coeffs_interior () const

  *Returns coefficients for the interior of the grid.*

- Real * weights_crs (void) const

  *Returns collection of weights as computed by the CRSA.*

- Real * weights_cbs (void) const

  *Returns collection of weights as computed by the CBSA.*

- DenseMatrix mim_bndy () const

  *Return collection of mimetic approximations at the boundary.*

- DenseMatrix ReturnAsDenseMatrix (Real west, Real east, int num_cells_x) const

  *Returns the operator as a dense matrix.*

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  *Returns the operator as a dense matrix.*

- DenseMatrix ReturnAsDimensionlessDenseMatrix (int num_cells_x) const

  *Returns the operator as a dimensionless dense matrix.*

## Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  *Stage 1 of the CBS Algorithm.*

- bool ComputeRationalBasisNullSpace (void)

  *Stage 2.1 of the CBS Algorithm.*

- bool ComputePreliminaryApproximations (void)

  *Stage 2.2 of the CBS Algorithm.*

- bool ComputeWeights (void)

  *Stage 2.3 of the CBS Algorithm.*

- bool ComputeStencilBoundaryGrid (void)

  *Stage 2.4 of the CBS Algorithm.*

- bool AssembleOperator (void)

  *Stage 3 of the CBS Algorithm.*

## Private Attributes

- int order_accuracy_

  *Order of numerical accuracy of the operator.*

- int dim_null_

  *Dim. null-space for boundary approximations.*

- int num_bndy_approxs_

*Req. approximations at and near the boundary.*

- int num_bndy_coeffs_

  *Req. coeffs. per bndy pt. uni. order accuracy.*

- int gradient_length_

  *Length of the output array.*

- int minrow_

  *Row from the optimizer with the minimum rel. nor.*

- int row_

  *Row currently processed by the optimizer.*

- DenseMatrix rat_basis_null_space_

  *Rational b. null-space w. bndy.*

- Real * coeffs_interior_

  *Interior stencil.*

- Real * prem_apps_

  *2D array of boundary preliminary approximations.*

- Real * weights_crs_

  *Array containing weights from CRSA.*

- Real * weights_cbs_

  *Array containing weights from CBSA.*

- Real * mim_bndy_

  *Array containing mimetic boundary approximations.*

- Real * gradient_

  *Output array containing the operator and weights.*

- Real mimetic_threshold_

  *< Mimetic threshold.*

## Friends

- std::ostream & operator<< (std::ostream &stream, Grad1D &in)

  *Output stream operator for printing.*

### 16.8.1 Detailed Description

This class implements a 1D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 81 of file mtk_grad_1d.h.

### 16.8.2 Constructor & Destructor Documentation

#### 16.8.2.1 mtk::Grad1D::Grad1D ( )

Definition at line 129 of file mtk_grad_1d.cc.

#### 16.8.2.2 mtk::Grad1D::Grad1D ( const Grad1D & *grad* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

Definition at line 145 of file mtk_grad_1d.cc.

#### 16.8.2.3 mtk::Grad1D::~Grad1D ( )

Definition at line 161 of file mtk_grad_1d.cc.

### 16.8.3 Member Function Documentation

#### 16.8.3.1 bool mtk::Grad1D::AssembleOperator ( void ) [private]

Construct the output array with the operator and its weights.

1. The first entry of the array will contain the order of accuracy.
2. The second entry of the array will contain the collection of approximating coefficients for the interior of the grid.
3. The third entry will contain the collection of weights.
4. The next dim_null + 1 entries will contain the collections of approximating coefficients for the west boundary of the grid.

Definition at line 1499 of file mtk_grad_1d.cc.

#### 16.8.3.2 mtk::Real * mtk::Grad1D::coeffs_interior ( ) const

**Returns**

Coefficients for the interior of the grid.

Definition at line 326 of file mtk_grad_1d.cc.

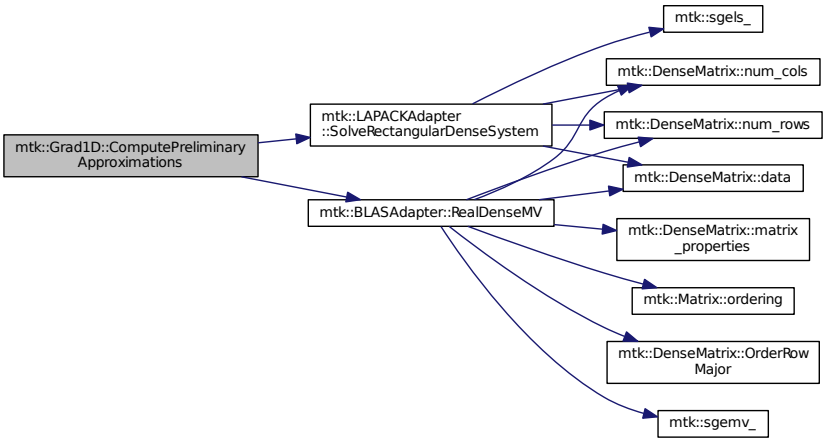
#### 16.8.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations ( void ) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the dim_null near-the-boundary columns of the pi matrix.
3. Create the Vandermonde matrix for this iteration.
4. New order-selector vector (gets re-written with LAPACK solutions).
5. Solving TT*rr = ob yields the columns rr of the kk matrix.
6. Scale the kk matrix to make it a rational basis for null-space.
7. Extract the last dim_null values of the pre-scaled ob.
8. Once we posses the bottom elements, we proceed with the scaling.

Definition at line 831 of file mtk_grad_1d.cc.

Here is the call graph for this function:




#### 16.8.3.4 bool mtk::Grad1D::ComputeRationalBasisNullSpace ( void ) [private]

Compute a rational basis for the null-space of the Vandermonde matrix approximating at the west boundary.

1. Create generator vector for the first approximation.

2. Create Vandermonde matrix.

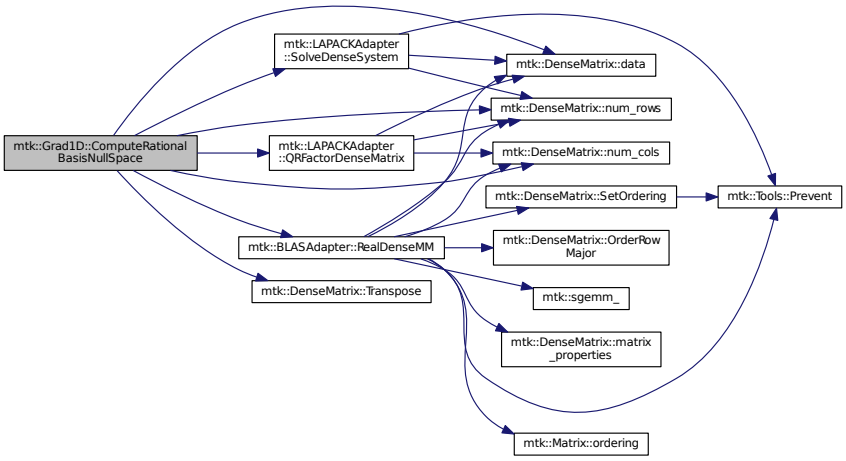
3. QR-factorize the Vandermonde matrix.

4. Extract the basis for the null-space from Q matrix.

5. Scale null-space to make it rational.

Definition at line 648 of file mtk_grad_1d.cc.

Here is the call graph for this function:




#### 16.8.3.5 bool mtk::Grad1D::ComputeStencilBoundaryGrid ( void ) [private]

Compute mimetic stencil approximating at boundary.

1. Collect lambda values.
2. Compute alpha values.
3. Compute the mimetic boundary approximations.

Definition at line 1393 of file mtk_grad_1d.cc.

#### 16.8.3.6 bool mtk::Grad1D::ComputeStencilInteriorGrid ( void ) [private]

Compute the stencil approximating the interior of the staggered grid.

1. Create vector for interior spatial coordinates.
2. Create Vandermonde matrix (using interior coordinates as generator).
3. Create order-selector vector.
4. Solve dense Vandermonde system to attain the interior coefficients.

Definition at line 551 of file mtk_grad_1d.cc.

Here is the call graph for this function:

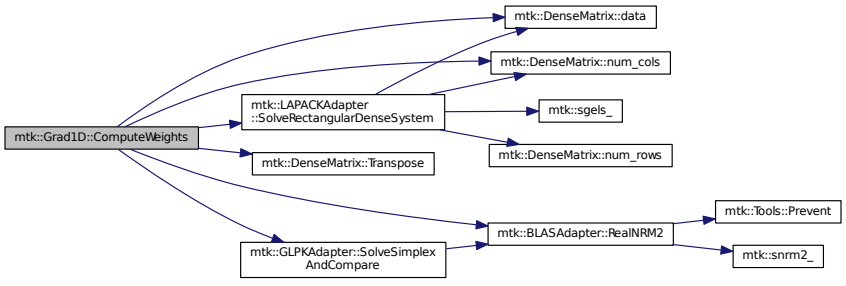

#### 16.8.3.7 bool mtk::Grad1D::ComputeWeights ( void ) [private]

Compute the set of mimetic weights to impose the mimetic condition.

1. Construct the ■ matrix.
2. Use interior stencil to build proper RHS vector $\mathbf{h}$.
3. Get weights (as **CRSA**): $\blacksquare\mathbf{q} = \mathbf{h}$.
4. If required order is greater than critical order, start the **CBSA**.
5. Create ■ matrix from ■.
6. Prepare constraint vector as in the CBSA: ■.
7. Brute force search through all the rows of the $\Phi$ matrix.
8. Apply solution found from brute force search.

Definition at line 1052 of file mtk_grad_1d.cc.

Here is the call graph for this function:




#### 16.8.3.8 bool mtk::Grad1D::ConstructGrad1D ( int *order_accuracy* = kDefaultOrderAccuracy, Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

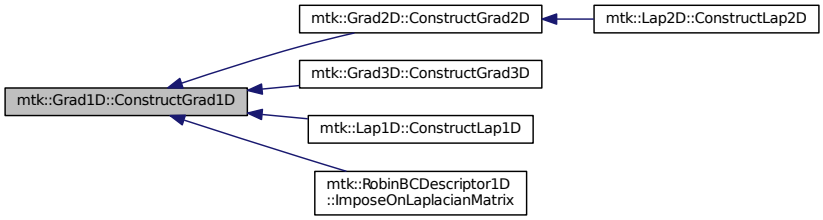
Success of the solution.

1. Compute stencil for the interior cells.
2. Compute a rational null-space from the first matrix transposed.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.
6. Assemble operator.

Definition at line 182 of file mtk_grad_1d.cc.

Here is the call graph for this function:


Here is the caller graph for this function:



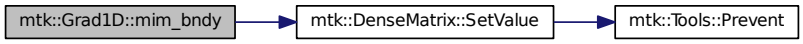

#### 16.8.3.9 mtk::DenseMatrix mtk::Grad1D::mim_bndy ( ) const

**Returns**

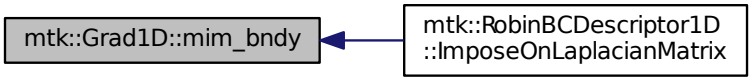
Collection of mimetic approximations at the boundary.

Definition at line 341 of file mtk_grad_1d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.8.3.10 int mtk::Grad1D::num_bndy_coeffs ( ) const

**Returns**

How many coefficients are approximating at the boundary.

Definition at line 321 of file mtk_grad_1d.cc.

#### 16.8.3.11 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix ( mtk::Real *west*, mtk::Real *east*, int *num_cells_x* ) const

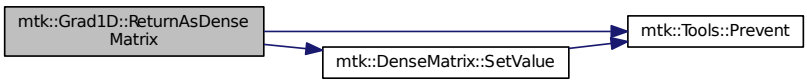
**Returns**

The operator as a dense matrix.

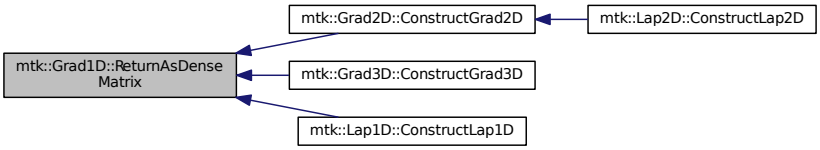
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 356 of file mtk_grad_1d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.8.3.12 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix ( const UniStgGrid1D & *grid* ) const

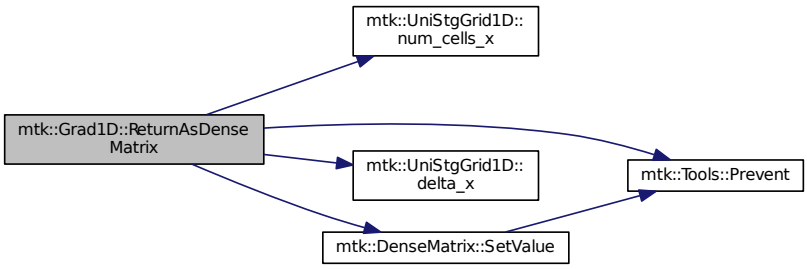
**Returns**

The operator as a dense matrix.

1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 425 of file mtk_grad_1d.cc.

Here is the call graph for this function:



#### 16.8.3.13 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix ( int *num_cells_x* ) const

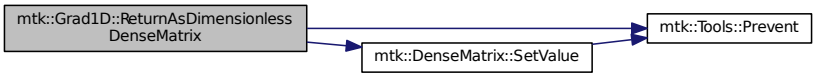
**Returns**

The operator as a dimensionless dense matrix.

1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 489 of file mtk_grad_1d.cc.

Here is the call graph for this function:




#### 16.8.3.14 mtk::Real * mtk::Grad1D::weights_cbs ( void ) const

**Returns**

Collection of weights as computed by the CBSA.

Definition at line 336 of file mtk_grad_1d.cc.

#### 16.8.3.15 mtk::Real * mtk::Grad1D::weights_crs ( void ) const

**Returns**

Success of the solution.

Definition at line 331 of file mtk_grad_1d.cc.

### 16.8.4 Friends And Related Function Documentation

#### 16.8.4.1 std::ostream& operator<< ( std::ostream & *stream*, mtk::Grad1D & *in* ) [friend]

1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. Print mimetic weights.
4. Print mimetic approximations at the boundary.

Definition at line 79 of file mtk_grad_1d.cc.

### 16.8.5 Member Data Documentation

#### 16.8.5.1 Real* mtk::Grad1D::coeffs_interior_ [private]

Definition at line 217 of file mtk_grad_1d.h.

#### 16.8.5.2 int mtk::Grad1D::dim_null_ [private]

Definition at line 208 of file mtk_grad_1d.h.

#### 16.8.5.3 Real* mtk::Grad1D::gradient_ [private]

Definition at line 222 of file mtk_grad_1d.h.

#### 16.8.5.4 int mtk::Grad1D::gradient_length_ [private]

Definition at line 211 of file mtk_grad_1d.h.

#### 16.8.5.5 Real* mtk::Grad1D::mim_bndy_ [private]

Definition at line 221 of file mtk_grad_1d.h.

#### 16.8.5.6 Real mtk::Grad1D::mimetic_threshold_ [private]

Definition at line 224 of file mtk_grad_1d.h.

#### 16.8.5.7 int mtk::Grad1D::minrow_ [private]

Definition at line 212 of file mtk_grad_1d.h.

#### 16.8.5.8 int mtk::Grad1D::num_bndy_approxs_ [private]

Definition at line 209 of file mtk_grad_1d.h.

#### 16.8.5.9 int mtk::Grad1D::num_bndy_coeffs_ [private]

Definition at line 210 of file mtk_grad_1d.h.

#### 16.8.5.10 int mtk::Grad1D::order_accuracy_ [private]

Definition at line 207 of file mtk_grad_1d.h.

#### 16.8.5.11 Real* mtk::Grad1D::prem_apps_ [private]

Definition at line 218 of file mtk_grad_1d.h.

#### 16.8.5.12 DenseMatrix mtk::Grad1D::rat_basis_null_space_ [private]

Definition at line 215 of file mtk_grad_1d.h.

#### 16.8.5.13 int mtk::Grad1D::row_ [private]

Definition at line 213 of file mtk_grad_1d.h.

#### 16.8.5.14 Real* mtk::Grad1D::weights_cbs_ [private]

Definition at line 220 of file mtk_grad_1d.h.

#### 16.8.5.15 Real* mtk::Grad1D::weights_crs_ [private]

Definition at line 219 of file mtk_grad_1d.h.

The documentation for this class was generated from the following files:

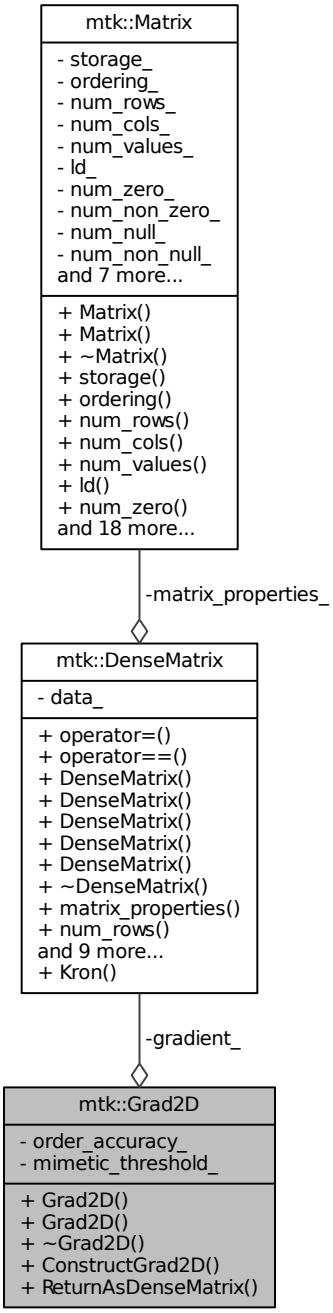
- include/mtk_grad_1d.h
- src/mtk_grad_1d.cc

## 16.9 mtk::Grad2D Class Reference

Implements a 2D mimetic gradient operator.

`#include <mtk_grad_2d.h>`

Collaboration diagram for mtk::Grad2D:




## Public Member Functions

- Grad2D ()

*Default constructor.*

- Grad2D (const Grad2D &grad)

  *Copy constructor.*

- ~Grad2D ()

  *Destructor.*

- bool ConstructGrad2D (const UniStgGrid2D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix gradient_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.9.1 Detailed Description

This class implements a 2D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_grad_2d.h.

## 16.9.2 Constructor & Destructor Documentation

### 16.9.2.1 mtk::Grad2D::Grad2D ( )

Definition at line 67 of file mtk_grad_2d.cc.

### 16.9.2.2 mtk::Grad2D::Grad2D ( const Grad2D & *grad* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

Definition at line 71 of file mtk_grad_2d.cc.

### 16.9.2.3 mtk::Grad2D::~Grad2D ( )

Definition at line 75 of file mtk_grad_2d.cc.

### 16.9.3 Member Function Documentation

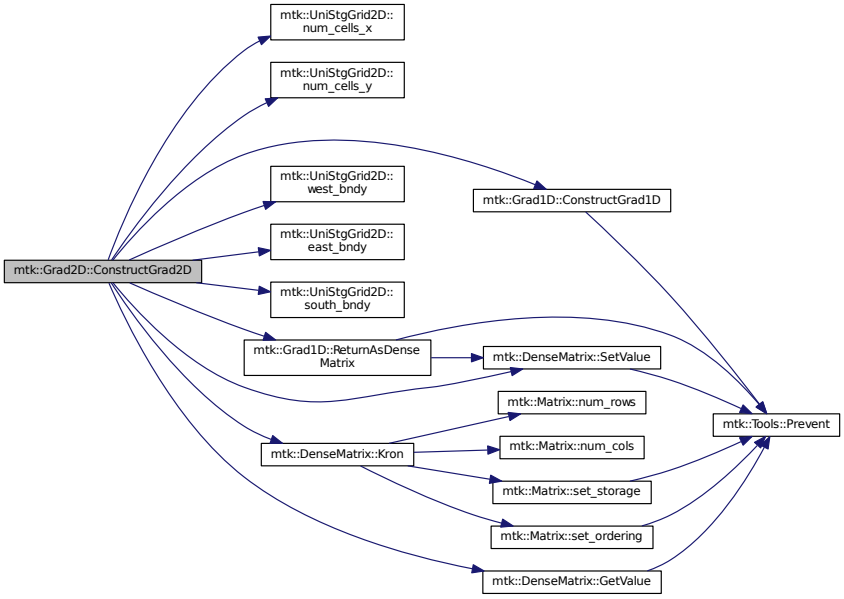
#### 16.9.3.1 bool mtk::Grad2D::ConstructGrad2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

Definition at line 77 of file mtk_grad_2d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:

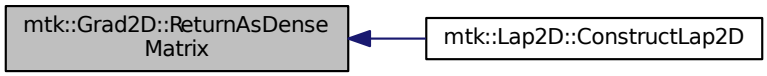

#### 16.9.3.2 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

Definition at line 145 of file mtk_grad_2d.cc.

Here is the caller graph for this function:




### 16.9.4 Member Data Documentation

#### 16.9.4.1 DenseMatrix mtk::Grad2D::gradient_ [private]

Definition at line 108 of file mtk_grad_2d.h.

#### 16.9.4.2 Real mtk::Grad2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_grad_2d.h.

#### 16.9.4.3 int mtk::Grad2D::order_accuracy_ [private]

Definition at line 110 of file mtk_grad_2d.h.

The documentation for this class was generated from the following files:

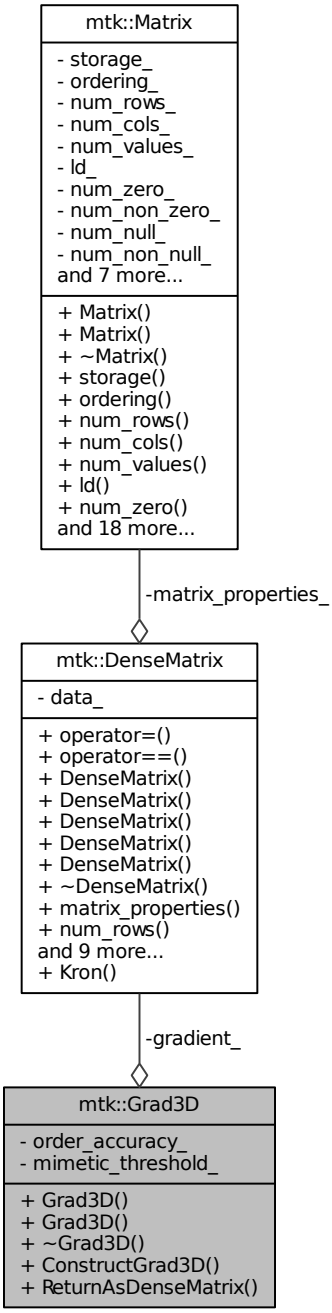
- include/mtk_grad_2d.h
- src/mtk_grad_2d.cc

## 16.10 mtk::Grad3D Class Reference

Implements a 3D mimetic gradient operator.

`#include <mtk_grad_3d.h>`

Collaboration diagram for mtk::Grad3D:




## Public Member Functions

- Grad3D ()

*Default constructor.*

- Grad3D (const Grad3D &grad)

  *Copy constructor.*

- ~Grad3D ()

  *Destructor.*

- bool ConstructGrad3D (const UniStgGrid3D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix gradient_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.10.1 Detailed Description

This class implements a 3D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_grad_3d.h.

## 16.10.2 Constructor & Destructor Documentation

### 16.10.2.1 mtk::Grad3D::Grad3D ( )

Definition at line 67 of file mtk_grad_3d.cc.

### 16.10.2.2 mtk::Grad3D::Grad3D ( const Grad3D & *grad* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given divergence. |

Definition at line 71 of file mtk_grad_3d.cc.

### 16.10.2.3 mtk::Grad3D::~Grad3D ( )

Definition at line 75 of file mtk_grad_3d.cc.

### 16.10.3 Member Function Documentation

#### 16.10.3.1 bool mtk::Grad3D::ConstructGrad3D ( const UniStgGrid3D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

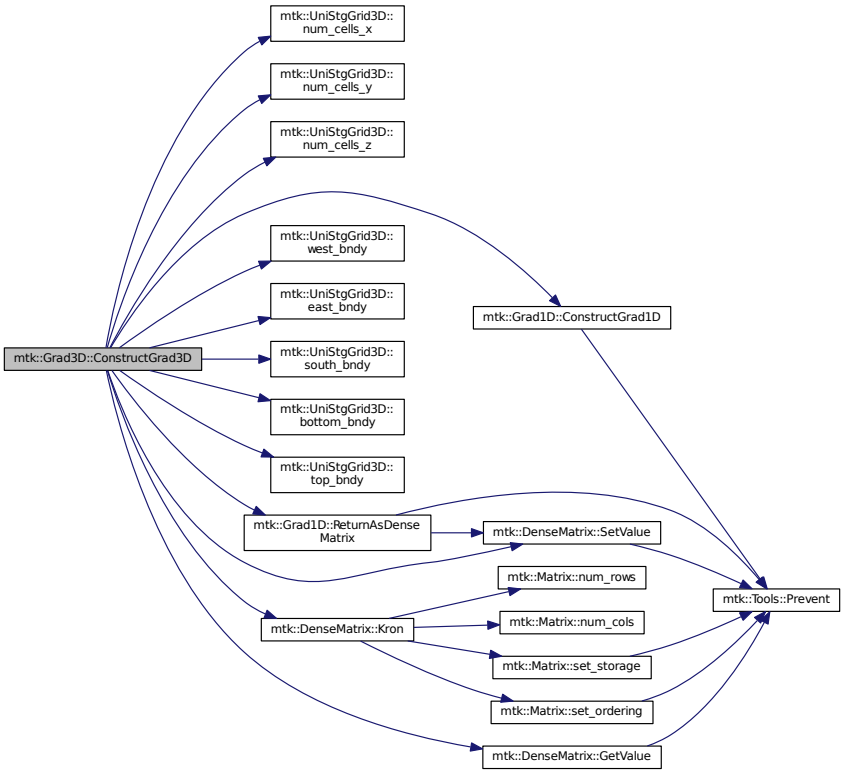
**Returns**

Success of the construction.

1. Build preliminary staggering through the x direction.
2. Build preliminary staggering through the y direction.
3. Build preliminary staggering through the z direction.
4. Actual operator: GG_xyz = [gx; gy; gz].

Definition at line 77 of file mtk_grad_3d.cc.

Here is the call graph for this function:




#### 16.10.3.2 mtk::DenseMatrix mtk::Grad3D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

Definition at line 185 of file mtk_grad_3d.cc.

### 16.10.4 Member Data Documentation

#### 16.10.4.1 DenseMatrix mtk::Grad3D::gradient_ [private]

Definition at line 108 of file mtk_grad_3d.h.

#### 16.10.4.2 Real mtk::Grad3D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_grad_3d.h.

#### 16.10.4.3 int mtk::Grad3D::order_accuracy_ [private]

Definition at line 110 of file mtk_grad_3d.h.

The documentation for this class was generated from the following files:

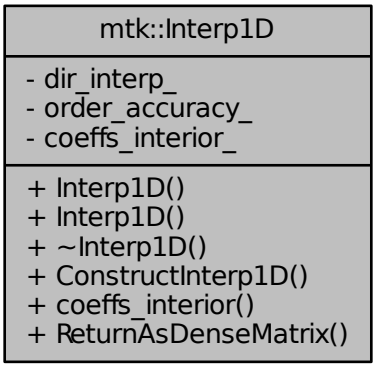
- include/mtk_grad_3d.h
- src/mtk_grad_3d.cc

## 16.11 mtk::Interp1D Class Reference

Implements a 1D interpolation operator.

`#include <mtk_interp_1d.h>`

Collaboration diagram for mtk::Interp1D:



### Public Member Functions

- Interp1D ()

  *Default constructor.*
- Interp1D (const Interp1D &interp)

  *Copy constructor.*
- ~Interp1D ()

  *Destructor.*
- bool ConstructInterp1D (int order_accuracy=kDefaultOrderAccuracy, mtk::DirInterp dir=SCALAR_TO_VECTOR)

  *Factory method to build operator.*
- Real * coeffs_interior () const

  *Returns coefficients for the interior of the grid.*
- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  *Returns the operator as a dense matrix.*

### Private Attributes

- DirInterp dir_interp_

  *Direction of interpolation.*
- int order_accuracy_

  *Order of numerical accuracy of the operator.*
- Real * coeffs_interior_

  *Interior stencil.*

### Friends

- std::ostream & operator<< (std::ostream &stream, Interp1D &in)

  *Output stream operator for printing.*

## 16.11.1 Detailed Description

This class implements a 1D interpolation operator.

Definition at line 82 of file mtk_interp_1d.h.

## 16.11.2 Constructor & Destructor Documentation

#### 16.11.2.1 mtk::Interp1D::Interp1D ( )

Definition at line 80 of file mtk_interp_1d.cc.

#### 16.11.2.2 mtk::Interp1D::Interp1D ( const Interp1D & *interp* )

**Parameters**

| | | |
|---|---|---|
| in | *interp* | Given interpolation operator. |

Definition at line 85 of file mtk_interp_1d.cc.

#### 16.11.2.3 mtk::Interp1D::~Interp1D ( )

Definition at line 90 of file mtk_interp_1d.cc.

### 16.11.3 Member Function Documentation

#### 16.11.3.1 mtk::Real * mtk::Interp1D::coeffs_interior ( ) const

**Returns**

Coefficients for the interior of the grid.

Definition at line 132 of file mtk_interp_1d.cc.

#### 16.11.3.2 bool mtk::Interp1D::ConstructInterp1D ( int *order_accuracy* = kDefaultOrderAccuracy, mtk::DirInterp *dir* = SCALAR_TO_VECTOR )

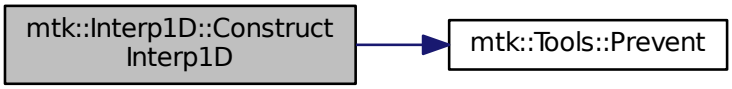
**Returns**

Success of the solution.

1. Compute stencil for the interior cells.

Definition at line 96 of file mtk_interp_1d.cc.

Here is the call graph for this function:




#### 16.11.3.3 mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix ( const UniStgGrid1D & *grid* ) const

**Returns**

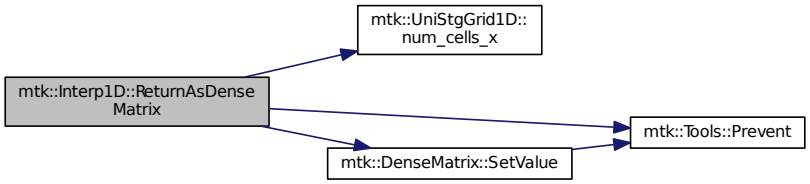
The operator as a dense matrix.

1. Preserve values at the boundary.
2. Insert coefficients for the interior of the grid.

3. Impose center-skew symmetry by permuting the boundaries.

Definition at line 137 of file mtk_interp_1d.cc.

Here is the call graph for this function:




### 16.11.4 Friends And Related Function Documentation

#### 16.11.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::Interp1D & *in* ) [friend]

1. Print approximating coefficients for the interior.

Definition at line 66 of file mtk_interp_1d.cc.

### 16.11.5 Member Data Documentation

#### 16.11.5.1 Real* mtk::Interp1D::coeffs_interior_ [private]

Definition at line 127 of file mtk_interp_1d.h.

#### 16.11.5.2 DirInterp mtk::Interp1D::dir_interp_ [private]

Definition at line 123 of file mtk_interp_1d.h.

#### 16.11.5.3 int mtk::Interp1D::order_accuracy_ [private]

Definition at line 125 of file mtk_interp_1d.h.

The documentation for this class was generated from the following files:

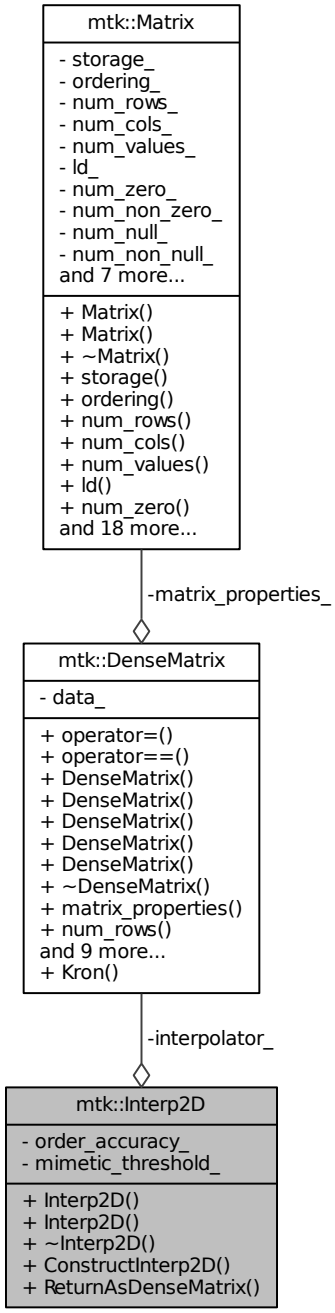
- include/mtk_interp_1d.h
- src/mtk_interp_1d.cc

## 16.12 mtk::Interp2D Class Reference

Implements a 2D interpolation operator.

`#include <mtk_interp_2d.h>`

Collaboration diagram for mtk::Interp2D:




## Public Member Functions

- Interp2D ()

*Default constructor.*

- Interp2D (const Interp2D &interp)

  *Copy constructor.*

- ~Interp2D ()

  *Destructor.*

- DenseMatrix ConstructInterp2D (const UniStgGrid2D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix ()

  *Return the operator as a dense matrix.*

### Private Attributes

- DenseMatrix interpolator_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.12.1 Detailed Description

This class implements a 2D interpolation operator.

Definition at line 76 of file mtk_interp_2d.h.

## 16.12.2 Constructor & Destructor Documentation

#### 16.12.2.1 mtk::Interp2D::Interp2D ( )

#### 16.12.2.2 mtk::Interp2D::Interp2D ( const Interp2D & *interp* )

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Given Laplacian. |

#### 16.12.2.3 mtk::Interp2D::~Interp2D ( )

## 16.12.3 Member Function Documentation

#### 16.12.3.1 DenseMatrix mtk::Interp2D::ConstructInterp2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

#### 16.12.3.2 DenseMatrix mtk::Interp2D::ReturnAsDenseMatrix ( )

**Returns**

The operator as a dense matrix.

### 16.12.4 Member Data Documentation

#### 16.12.4.1 DenseMatrix mtk::Interp2D::interpolator_ [private]

Definition at line 108 of file mtk_interp_2d.h.

#### 16.12.4.2 Real mtk::Interp2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_interp_2d.h.

#### 16.12.4.3 int mtk::Interp2D::order_accuracy_ [private]

Definition at line 110 of file mtk_interp_2d.h.

The documentation for this class was generated from the following file:

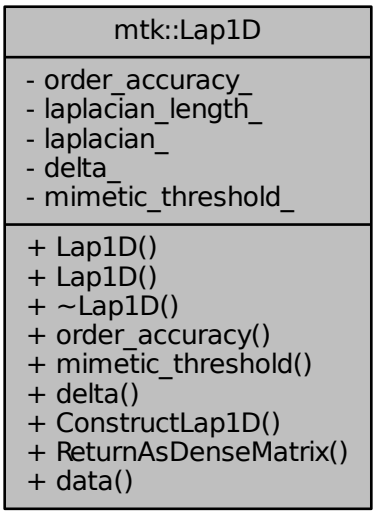
- include/mtk_interp_2d.h

## 16.13 mtk::Lap1D Class Reference

Implements a 1D mimetic Laplacian operator.

`#include <mtk_lap_1d.h>`

Collaboration diagram for mtk::Lap1D:




## Public Member Functions

- Lap1D ()

  *Default constructor.*
- Lap1D (const Lap1D &lap)

  *Copy constructor.*
- ~Lap1D ()

  *Destructor.*
- int order_accuracy () const

  *Order of accuracy of the operator.*
- Real mimetic_threshold () const

  *Mimetic threshold used in the CBS algorithm to construct this operator.*
- Real delta () const

  *Value of $\Delta x$ used be scaled. If 0, then dimensionless.*
- bool ConstructLap1D (int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimetic↩Threshold)

  *Factory method implementing the CBS Algorithm to build operator.*
- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  *Return the operator as a dense matrix.*
- const mtk::Real * data (const UniStgGrid1D &grid) const

  *Return the operator as a dense array.*

### Private Attributes

- int order_accuracy_

  *Order of numerical accuracy of the operator.*
- int laplacian_length_

  *Length of the output array.*
- Real * laplacian_

  *Output array containing the operator and weights.*
- Real delta_

  *< If 0.0, then this Laplacian is dimensionless.*
- Real mimetic_threshold_

  *< Mimetic threshold.*

### Friends

- std::ostream & operator<< (std::ostream &stream, Lap1D &in)

  *Output stream operator for printing.*

## 16.13.1 Detailed Description

This class implements a 1D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_lap_1d.h.

## 16.13.2 Constructor & Destructor Documentation

#### 16.13.2.1 mtk::Lap1D::Lap1D ( )

Definition at line 108 of file mtk_lap_1d.cc.

#### 16.13.2.2 mtk::Lap1D::Lap1D ( const Lap1D & *lap* )

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Given Laplacian. |

#### 16.13.2.3 mtk::Lap1D::~Lap1D ( )

Definition at line 114 of file mtk_lap_1d.cc.

## 16.13.3 Member Function Documentation

#### 16.13.3.1 bool mtk::Lap1D::ConstructLap1D ( int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

### Returns

Success of the solution.

1. Create gradient operator using specific values for the Laplacian.
2. Create gradient operator using specific values for the Laplacian.
3. Create both operators as matrices.
4. Multiply both operators: $\check{\mathbf{L}}_x^k = \check{\mathbf{D}}_x^k \check{\mathbf{G}}_x^k$
5. Extract the coefficients from the matrix and store them in the array.

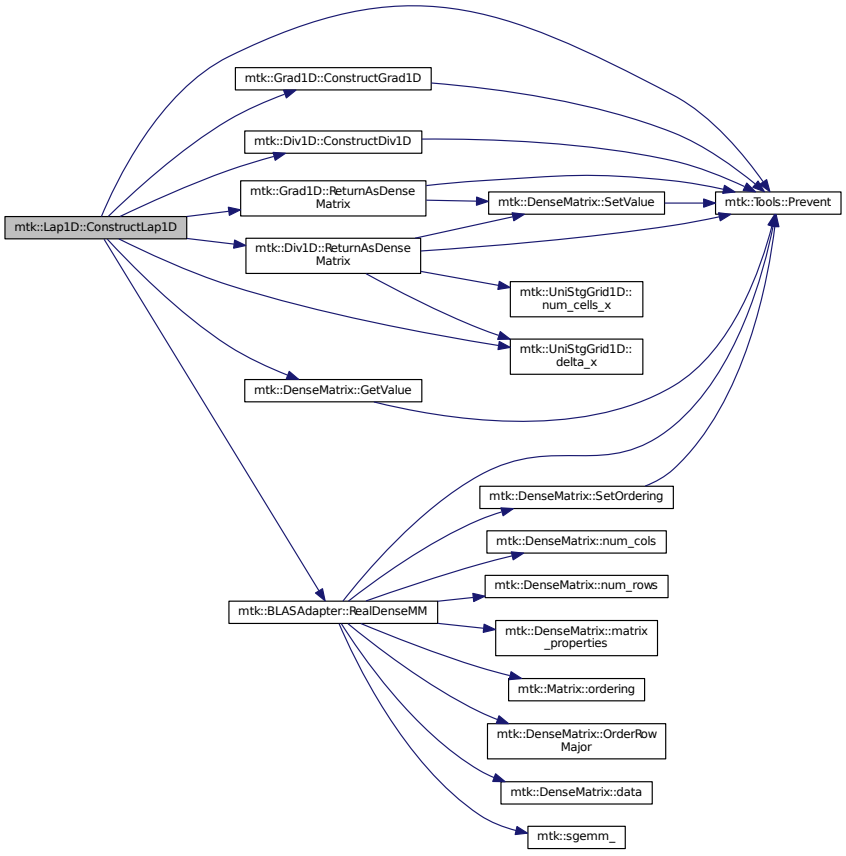
### Warning

We do not compute weights for this operator... no need to!

1. The first entry of the array will contain the order of accuracy.
2. The second entry of the array will contain the collection of approximating coefficients for the interior of the grid.
3. We DO NOT have weights in this operator. Copy mimetic bndy coeffs.

Definition at line 135 of file mtk_lap_1d.cc.

Here is the call graph for this function:



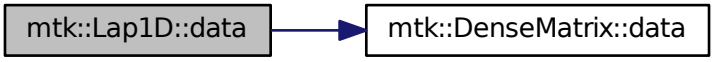
#### 16.13.3.2 const mtk::Real * mtk::Lap1D::data ( const UniStgGrid1D & *grid* ) const

**Returns**

The operator as a dense array.

Definition at line 356 of file mtk_lap_1d.cc.

Here is the call graph for this function:



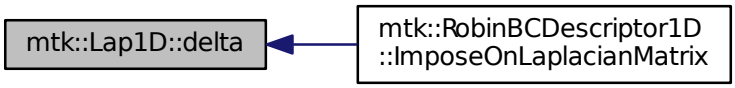

#### 16.13.3.3 mtk::Real mtk::Lap1D::delta ( ) const

**Returns**

Value of $\Delta x$ used be scaled. If 0, then dimensionless.

Definition at line 130 of file mtk_lap_1d.cc.

Here is the caller graph for this function:



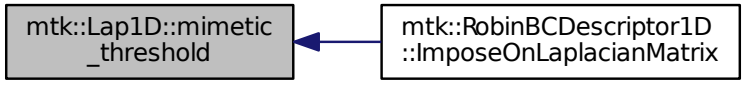

#### 16.13.3.4 mtk::Real mtk::Lap1D::mimetic_threshold ( ) const

**Returns**

Mimetic threshold used in the CBS algorithm to construct operator.

Definition at line 125 of file mtk_lap_1d.cc.

Here is the caller graph for this function:



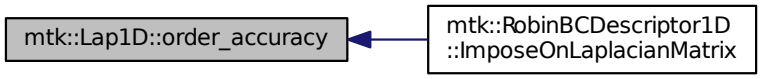

#### 16.13.3.5 int mtk::Lap1D::order_accuracy ( ) const

**Returns**

Order of accuracy of the operator.

Definition at line 120 of file mtk_lap_1d.cc.

Here is the caller graph for this function:




#### 16.13.3.6 mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix ( const UniStgGrid1D & *grid* ) const

**Returns**

The operator as a dense matrix.

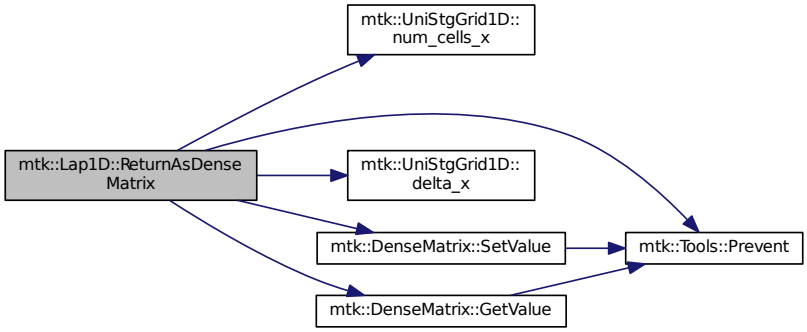
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

**Note**

We could create two matrices of the requested size and multiply them, but that would be inefficient, since we already have the computed coefficients stored. We just have to set them in place, in a matrix of an adequate size, and multiply them times the inverse of the square of the step size, in order for the matrix to actually represent a differential operator.

Definition at line 286 of file mtk_lap_1d.cc.

Here is the call graph for this function:




### 16.13.4 Friends And Related Function Documentation

#### 16.13.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::Lap1D & *in* ) [friend]

1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 73 of file mtk_lap_1d.cc.

### 16.13.5 Member Data Documentation

#### 16.13.5.1 Real mtk::Lap1D::delta_ [mutable], [private]

Definition at line 143 of file mtk_lap_1d.h.

#### 16.13.5.2 Real* mtk::Lap1D::laplacian_ [private]

Definition at line 141 of file mtk_lap_1d.h.

#### 16.13.5.3 int mtk::Lap1D::laplacian_length_ [private]

Definition at line 139 of file mtk_lap_1d.h.

#### 16.13.5.4 Real mtk::Lap1D::mimetic_threshold_ [private]

Definition at line 145 of file mtk_lap_1d.h.

#### 16.13.5.5 int mtk::Lap1D::order_accuracy_ [private]

Definition at line 138 of file mtk_lap_1d.h.

The documentation for this class was generated from the following files:

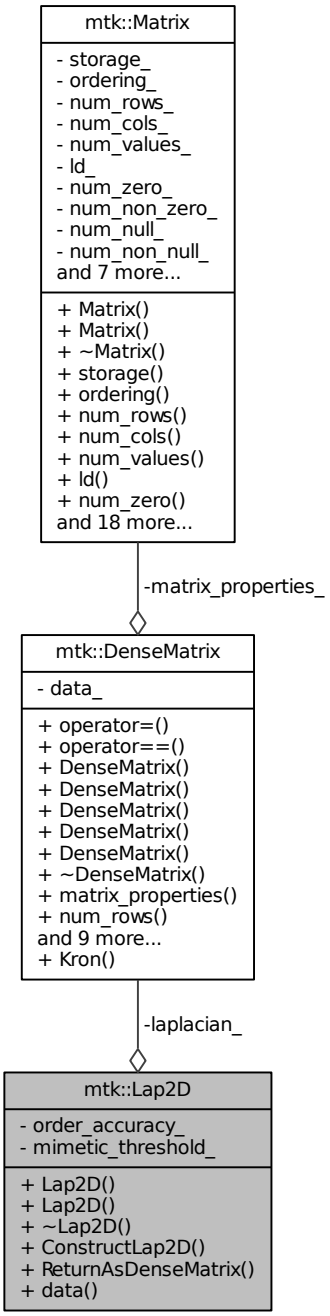
- include/mtk_lap_1d.h
- src/mtk_lap_1d.cc

## 16.14 mtk::Lap2D Class Reference

Implements a 2D mimetic Laplacian operator.

`#include <mtk_lap_2d.h>`

Collaboration diagram for mtk::Lap2D:




## Public Member Functions

- Lap2D ()

*Default constructor.*

- Lap2D (const Lap2D &lap)

  *Copy constructor.*

- ~Lap2D ()

  *Destructor.*

- bool ConstructLap2D (const UniStgGrid2D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

- Real * data () const

  *Return the operator as a dense array.*

### Private Attributes

- DenseMatrix laplacian_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.14.1 Detailed Description

This class implements a 2D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_lap_2d.h.

## 16.14.2 Constructor & Destructor Documentation

### 16.14.2.1 mtk::Lap2D::Lap2D ( )

Definition at line 69 of file mtk_lap_2d.cc.

### 16.14.2.2 mtk::Lap2D::Lap2D ( const Lap2D & *lap* )

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Given Laplacian. |

Definition at line 71 of file mtk_lap_2d.cc.

### 16.14.2.3 mtk::Lap2D::~Lap2D ( )

Definition at line 75 of file mtk_lap_2d.cc.

### 16.14.3 Member Function Documentation

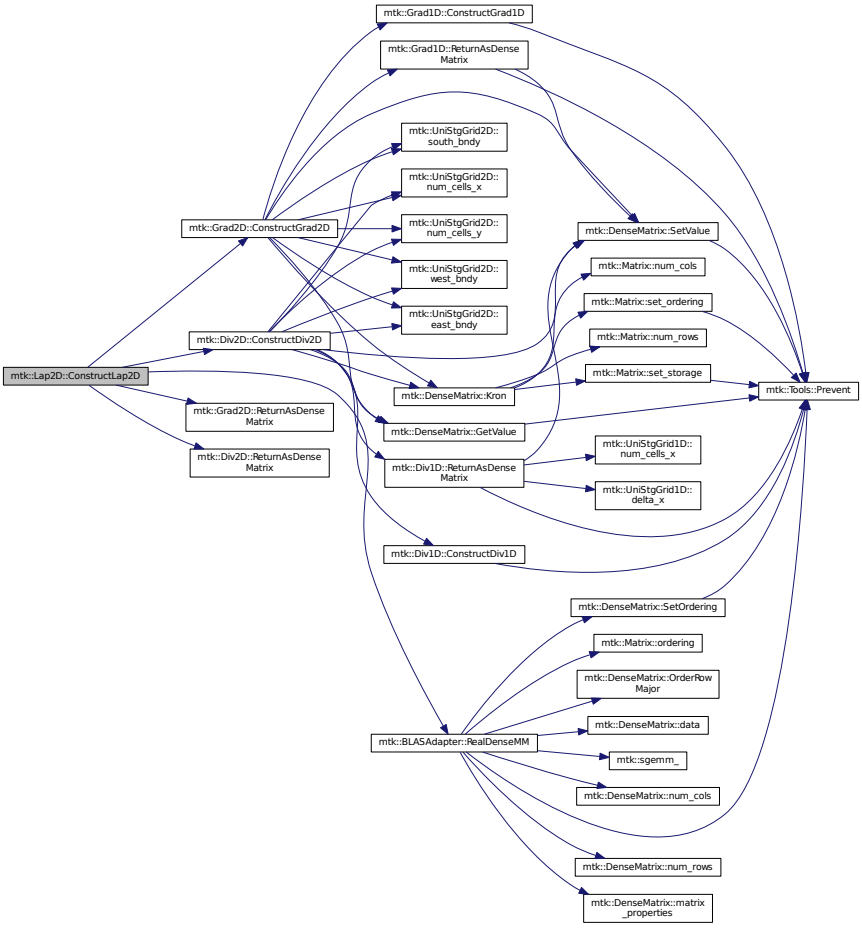
#### 16.14.3.1 bool mtk::Lap2D::ConstructLap2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

Definition at line 77 of file mtk_lap_2d.cc.

Here is the call graph for this function:




#### 16.14.3.2 mtk::Real * mtk::Lap2D::data ( ) const

**Returns**

The operator as a dense array.

Definition at line 115 of file mtk_lap_2d.cc.

#### 16.14.3.3 DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

Definition at line 110 of file mtk_lap_2d.cc.

### 16.14.4 Member Data Documentation

#### 16.14.4.1 DenseMatrix mtk::Lap2D::laplacian_ [private]

Definition at line 115 of file mtk_lap_2d.h.

#### 16.14.4.2 Real mtk::Lap2D::mimetic_threshold_ [private]

Definition at line 119 of file mtk_lap_2d.h.

#### 16.14.4.3 int mtk::Lap2D::order_accuracy_ [private]

Definition at line 117 of file mtk_lap_2d.h.

The documentation for this class was generated from the following files:

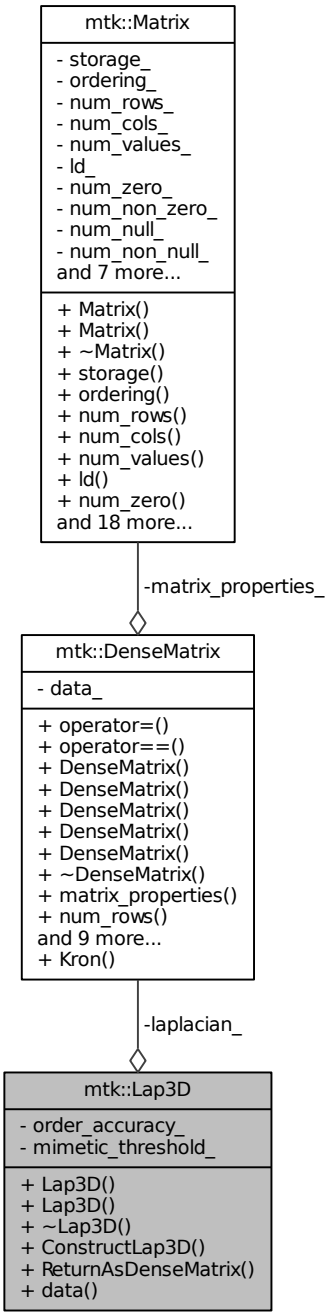
- include/mtk_lap_2d.h
- src/mtk_lap_2d.cc

## 16.15 mtk::Lap3D Class Reference

Implements a 3D mimetic Laplacian operator.

`#include <mtk_lap_3d.h>`

Collaboration diagram for mtk::Lap3D:




## Public Member Functions

- Lap3D ()

*Default constructor.*

- Lap3D (const Lap3D &lap)

  *Copy constructor.*

- ~Lap3D ()

  *Destructor.*

- bool ConstructLap3D (const UniStgGrid3D &grid, int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  *Factory method implementing the CBS Algorithm to build operator.*

- DenseMatrix ReturnAsDenseMatrix () const

  *Return the operator as a dense matrix.*

- Real * data () const

  *Return the operator as a dense array.*

### Private Attributes

- DenseMatrix laplacian_

  *Actual operator.*

- int order_accuracy_

  *Order of accuracy.*

- Real mimetic_threshold_

  *Mimetic Threshold.*

## 16.15.1 Detailed Description

This class implements a 3D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

Definition at line 76 of file mtk_lap_3d.h.

## 16.15.2 Constructor & Destructor Documentation

### 16.15.2.1 mtk::Lap3D::Lap3D ( )

### 16.15.2.2 mtk::Lap3D::Lap3D ( const Lap3D & *lap* )

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Given Laplacian. |

### 16.15.2.3 mtk::Lap3D::~Lap3D ( )

## 16.15.3 Member Function Documentation

### 16.15.3.1 bool mtk::Lap3D::ConstructLap3D ( const UniStgGrid3D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

#### 16.15.3.2 Real* mtk::Lap3D::data ( ) const

**Returns**

The operator as a dense array.

#### 16.15.3.3 DenseMatrix mtk::Lap3D::ReturnAsDenseMatrix ( ) const

**Returns**

The operator as a dense matrix.

### 16.15.4 Member Data Documentation

#### 16.15.4.1 DenseMatrix mtk::Lap3D::laplacian_ [private]

Definition at line 115 of file mtk_lap_3d.h.

#### 16.15.4.2 Real mtk::Lap3D::mimetic_threshold_ [private]

Definition at line 119 of file mtk_lap_3d.h.

#### 16.15.4.3 int mtk::Lap3D::order_accuracy_ [private]

Definition at line 117 of file mtk_lap_3d.h.

The documentation for this class was generated from the following file:

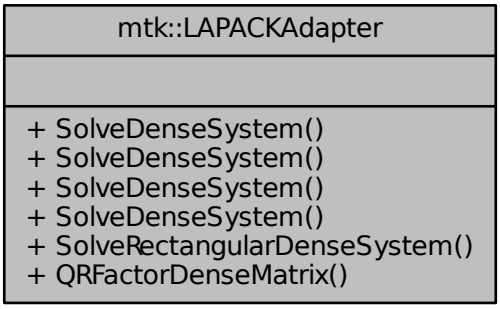
- include/mtk_lap_3d.h

## 16.16 mtk::LAPACKAdapter Class Reference

Adapter class for the LAPACK API.

`#include <mtk_lapack_adapter.h>`

Collaboration diagram for mtk::LAPACKAdapter:




### Static Public Member Functions

- static int SolveDenseSystem (mtk::DenseMatrix &mm, mtk::Real *rhs)

  *Solves a dense system of linear equations.*
- static int SolveDenseSystem (mtk::DenseMatrix &mm, mtk::DenseMatrix &rr)

  *Solves a dense system of linear equations.*
- static int SolveDenseSystem (mtk::DenseMatrix &mm, mtk::UniStgGrid1D &rhs)

  *Solves a dense system of linear equations.*
- static int SolveDenseSystem (mtk::DenseMatrix &mm, mtk::UniStgGrid2D &rhs)

  *Solves a dense system of linear equations.*
- static int SolveRectangularDenseSystem (const mtk::DenseMatrix &aa, mtk::Real *ob_, int ob_ld_)

  *Solves overdetermined or underdetermined real linear systems.*
- static mtk::DenseMatrix QRFactorDenseMatrix (DenseMatrix &matrix)

  *Performs a QR factorization on a dense matrix.*

### 16.16.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit the numerical methods implemented in the LAPACK.

The **LAPACK (Linear Algebra PACKage)** is written in Fortran 90 and provides routines for solving systems of simultaneous linear equations, least-squares solutions of linear systems of equations, eigenvalue problems, and singular value problems.

**See also**

http://www.netlib.org/lapack/

Definition at line 93 of file mtk_lapack_adapter.h.

## 16.16.2 Member Function Documentation

### 16.16.2.1 mtk::DenseMatrix mtk::LAPACKAdapter::QRFactorDenseMatrix ( mtk::DenseMatrix & *aa* ) [static]

Adapts the MTK to LAPACK's routine.

**Parameters**

| | | |
|---|---|---|
| in,out | *matrix* | Input matrix. |

**Returns**

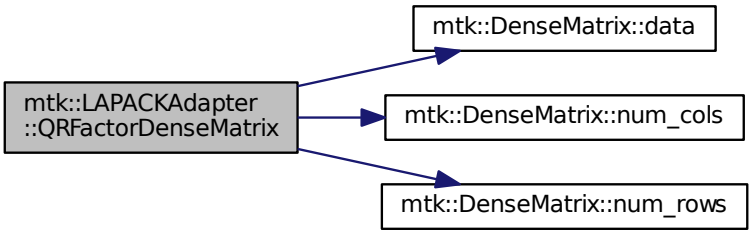
Matrix $\mathbf{Q}$.

**Exceptions**

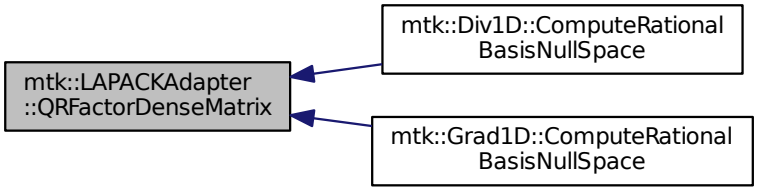
| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 593 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.16.2.2 int mtk::LAPACKAdapter::SolveDenseSystem ( mtk::DenseMatrix & *mm*, mtk::Real * *rhs* ) [static]

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

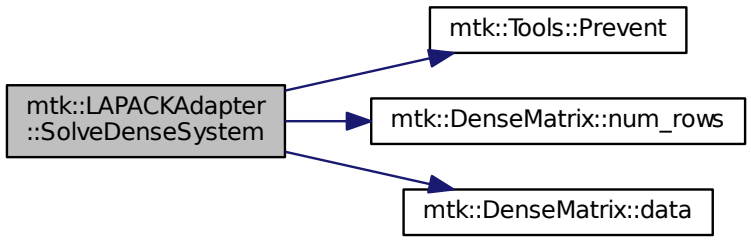
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rhs* | Input right-hand sides vector. |

**Exceptions**

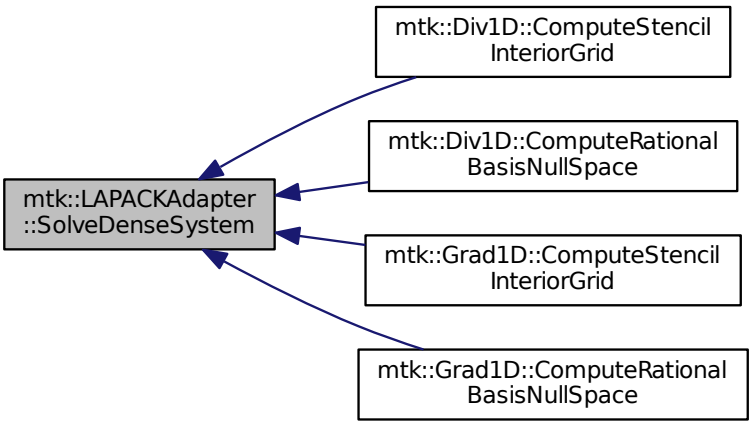
| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 430 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




#### 16.16.2.3 int mtk::LAPACKAdapter::SolveDenseSystem ( mtk::DenseMatrix & *mm*, mtk::DenseMatrix & *rr* ) [static]

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

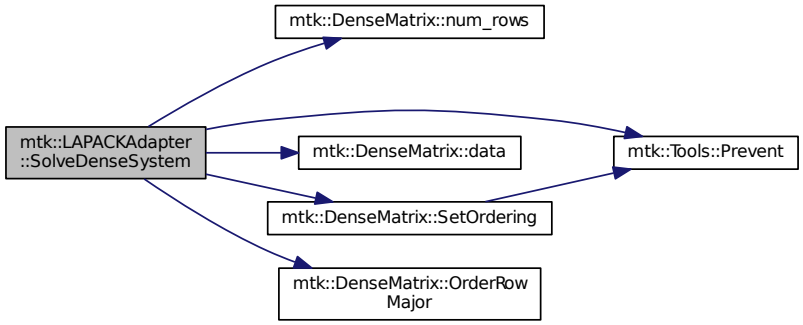
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rr* | Input right-hand sides matrix. |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 465 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




#### 16.16.2.4 int mtk::LAPACKAdapter::SolveDenseSystem ( mtk::DenseMatrix & *mm*, mtk::UniStgGrid1D & *rhs* ) [static]

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

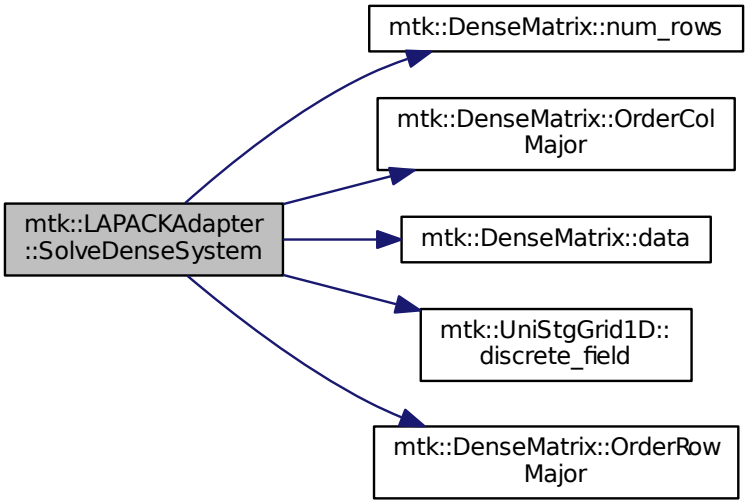
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rhs* | Input right-hand side from info on a grid. |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 517 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




#### 16.16.2.5 int mtk::LAPACKAdapter::SolveDenseSystem ( mtk::DenseMatrix & *mm*, mtk::UniStgGrid2D & *rhs* ) [static]

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

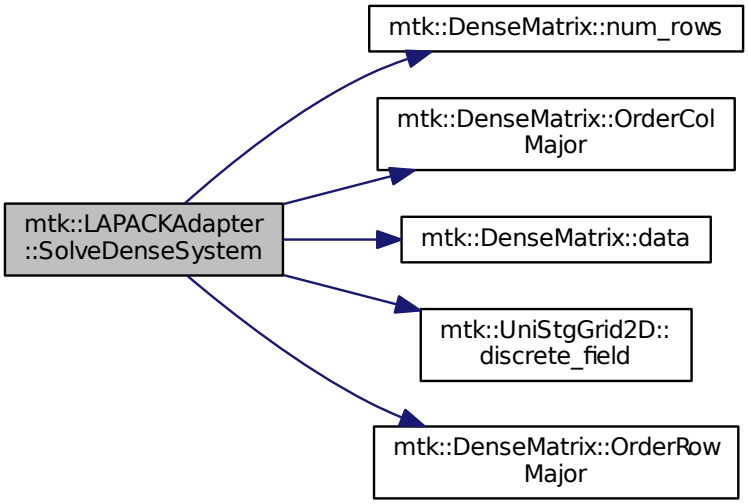
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rhs* | Input right-hand side from info on a grid. |

**Exceptions**

| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 555 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




#### 16.16.2.6 int mtk::LAPACKAdapter::SolveRectangularDenseSystem ( const mtk::DenseMatrix & *aa*, mtk::Real * *ob_*, int *ob_ld_* ) [static]

Adapts the MTK to LAPACK's routine.

**Parameters**

| | | |
|---|---|---|
| in,out | *matrix* | Input matrix. |

**Returns**

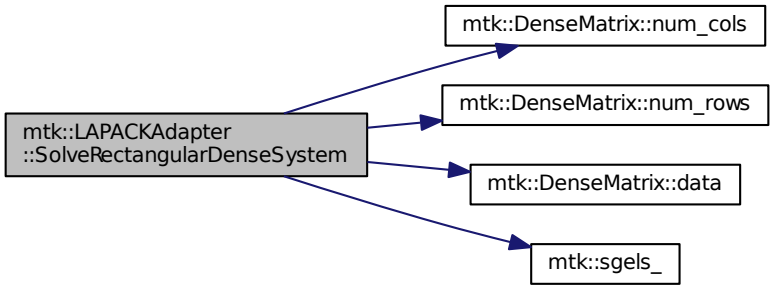
Success of the solution.

**Exceptions**

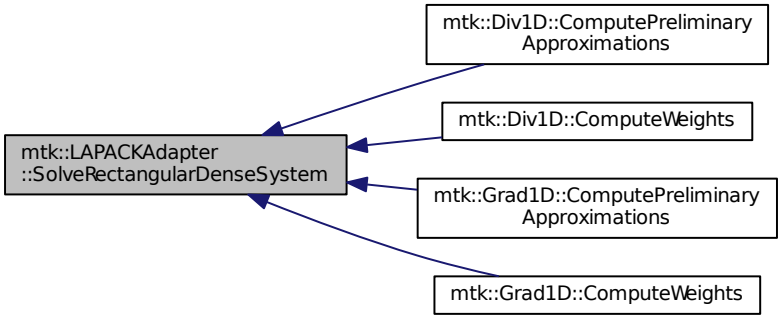
| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 790 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




The documentation for this class was generated from the following files:

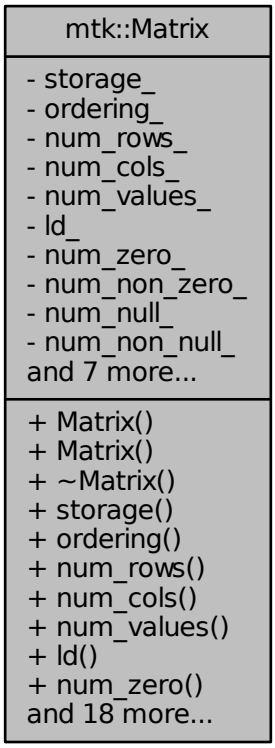
- include/mtk_lapack_adapter.h
- src/mtk_lapack_adapter.cc

## 16.17 mtk::Matrix Class Reference

Definition of the representation of a matrix in the MTK.

`#include <mtk_matrix.h>`

Collaboration diagram for mtk::Matrix:




## Public Member Functions

- Matrix ()

  *Default constructor.*
- Matrix (const Matrix &in)

  *Copy constructor.*
- ~Matrix () noexcept

  *Destructor.*
- MatrixStorage storage () const noexcept

  *Gets the type of storage of this matrix.*
- MatrixOrdering ordering () const noexcept

  *Gets the type of ordering of this matrix.*
- int num_rows () const noexcept

  *Gets the number of rows.*
- int num_cols () const noexcept

  *Gets the number of rows.*

- int num_values () const noexcept

  *Gets the number of values.*
- int ld () const noexcept

  *Gets the matrix' leading dimension.*
- int num_zero () const noexcept

  *Gets the number of zeros.*
- int num_non_zero () const noexcept

  *Gets the number of non-zero values.*
- int num_null () const noexcept

  *Gets the number of null values.*
- int num_non_null () const noexcept

  *Gets the number of non-null values.*
- int kl () const noexcept

  *Gets the number of lower diagonals.*
- int ku () const noexcept

  *Gets the number of upper diagonals.*
- int bandwidth () const noexcept

  *Gets the bandwidth.*
- Real abs_density () const noexcept

  *Gets the absolute density.*
- Real rel_density () const noexcept

  *Gets the relative density.*
- Real abs_sparsity () const noexcept

  *Gets the Absolute sparsity.*
- Real rel_sparsity () const noexcept

  *Gets the Relative sparsity.*
- void set_storage (const MatrixStorage &tt) noexcept

  *Sets the storage type of the matrix.*
- void set_ordering (const MatrixOrdering &oo) noexcept

  *Sets the ordering of the matrix.*
- void set_num_rows (const int &num_rows) noexcept

  *Sets the number of rows of the matrix.*
- void set_num_cols (const int &num_cols) noexcept

  *Sets the number of columns of the matrix.*
- void set_num_zero (const int &in) noexcept

  *Sets the number of zero values of the matrix that matter.*
- void set_num_null (const int &in) noexcept

  *Sets the number of zero values of the matrix that DO NOT matter.*
- void IncreaseNumZero () noexcept

  *Increases the number of values that equal zero but with meaning.*
- void IncreaseNumNull () noexcept

  *Increases the number of values that equal zero but with no meaning.*

### Private Attributes

- MatrixStorage storage_

  *What type of matrix is this?*
- MatrixOrdering ordering_

  *What kind of ordering is it following?*
- int num_rows_

  *Number of rows.*
- int num_cols_

  *Number of columns.*
- int num_values_

  *Number of total values in matrix.*
- int ld_

  *Elements between successive rows when row-major.*
- int num_zero_

  *Number of zeros.*
- int num_non_zero_

  *Number of non-zero values.*
- int num_null_

  *Number of null (insignificant) values.*
- int num_non_null_

  *Number of null (significant) values.*
- int kl_

  *Number of lower diagonals on a banded matrix.*
- int ku_

  *Number of upper diagonals on a banded matrix.*
- int bandwidth_

  *Bandwidth of the matrix.*
- Real abs_density_

  *Absolute density of matrix.*
- Real rel_density_

  *Relative density of matrix.*
- Real abs_sparsity_

  *Absolute sparsity of matrix.*
- Real rel_sparsity_

  *Relative sparsity of matrix.*

## 16.17.1 Detailed Description

Definition of the representation for the matrices implemented in the MTK.

Definition at line 75 of file mtk_matrix.h.

## 16.17.2 Constructor & Destructor Documentation

### 16.17.2.1 mtk::Matrix::Matrix ( )

Definition at line 67 of file mtk_matrix.cc.

#### 16.17.2.2 mtk::Matrix::Matrix ( const Matrix & *in* )

**Parameters**

| | | |
|---|---|---|
| in | *in* | Given matrix. |

Definition at line 86 of file mtk_matrix.cc.

#### 16.17.2.3 mtk::Matrix::~Matrix ( ) [noexcept]

Definition at line 105 of file mtk_matrix.cc.

### 16.17.3 Member Function Documentation

#### 16.17.3.1 Real mtk::Matrix::abs_density ( ) const [noexcept]

**See also**

http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Absolute density of the matrix.

#### 16.17.3.2 mtk::Real mtk::Matrix::abs_sparsity ( ) const [noexcept]

**See also**

http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Absolute sparsity of the matrix.

Definition at line 177 of file mtk_matrix.cc.

#### 16.17.3.3 int mtk::Matrix::bandwidth ( ) const [noexcept]

**Returns**

Bandwidth of the matrix.

Definition at line 167 of file mtk_matrix.cc.

#### 16.17.3.4 void mtk::Matrix::IncreaseNumNull ( ) [noexcept]

**Todo** Review the definition of sparse matrices properties.

Definition at line 274 of file mtk_matrix.cc.

#### 16.17.3.5 void mtk::Matrix::IncreaseNumZero ( ) [noexcept]

**Todo** Review the definition of sparse matrices properties.

Definition at line 264 of file mtk_matrix.cc.

#### 16.17.3.6 int mtk::Matrix::kl ( ) const [noexcept]

**Returns**

Number of lower diagonals.

Definition at line 157 of file mtk_matrix.cc.

#### 16.17.3.7 int mtk::Matrix::ku ( ) const [noexcept]

**Returns**

Number of upper diagonals.

Definition at line 162 of file mtk_matrix.cc.

#### 16.17.3.8 int mtk::Matrix::ld ( ) const [noexcept]

Leading dimension of the data array is the number of elements between successive rows (for row major storage) in memory. Most of the cases, the leading dimension is the same as the number of columns.

**Returns**

Leading dimension of the matrix.

Definition at line 132 of file mtk_matrix.cc.

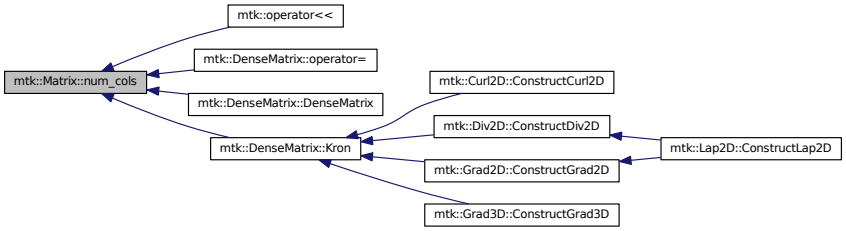
#### 16.17.3.9 int mtk::Matrix::num_cols ( ) const [noexcept]

**Returns**

Number of rows of the matrix.

Definition at line 122 of file mtk_matrix.cc.

Here is the caller graph for this function:



#### 16.17.3.10 int mtk::Matrix::num_non_null ( ) const [noexcept]

**See also**

http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Number of non-null values of the matrix.

Definition at line 152 of file mtk_matrix.cc.

#### 16.17.3.11 int mtk::Matrix::num_non_zero ( ) const [noexcept]

**Returns**

Number of non-zero values of the matrix.

Definition at line 142 of file mtk_matrix.cc.

#### 16.17.3.12 int mtk::Matrix::num_null ( ) const [noexcept]

**See also**

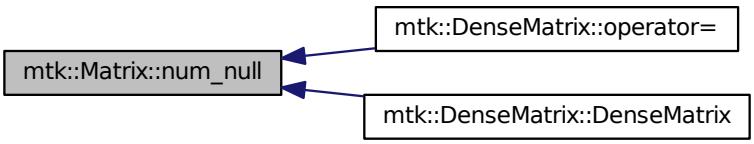
http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Number of null values of the matrix.

Definition at line 147 of file mtk_matrix.cc.

Here is the caller graph for this function:



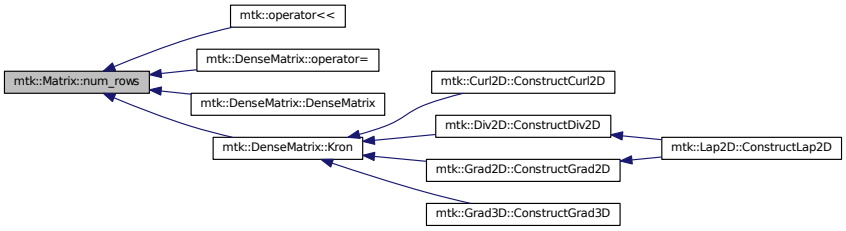

#### 16.17.3.13 int mtk::Matrix::num_rows ( ) const [noexcept]

**Returns**

Number of rows of the matrix.

Definition at line 117 of file mtk_matrix.cc.

Here is the caller graph for this function:




#### 16.17.3.14 int mtk::Matrix::num_values ( ) const [noexcept]

**Returns**

Number of values of the matrix.

Definition at line 127 of file mtk_matrix.cc.

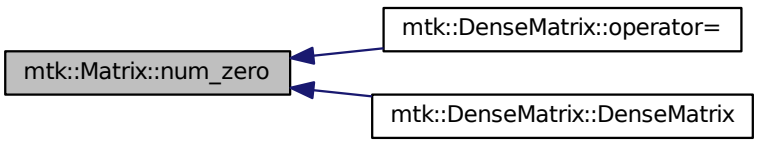
#### 16.17.3.15 int mtk::Matrix::num_zero ( ) const [noexcept]

**Returns**

Number of zeros of the matrix.

Definition at line 137 of file mtk_matrix.cc.

Here is the caller graph for this function:



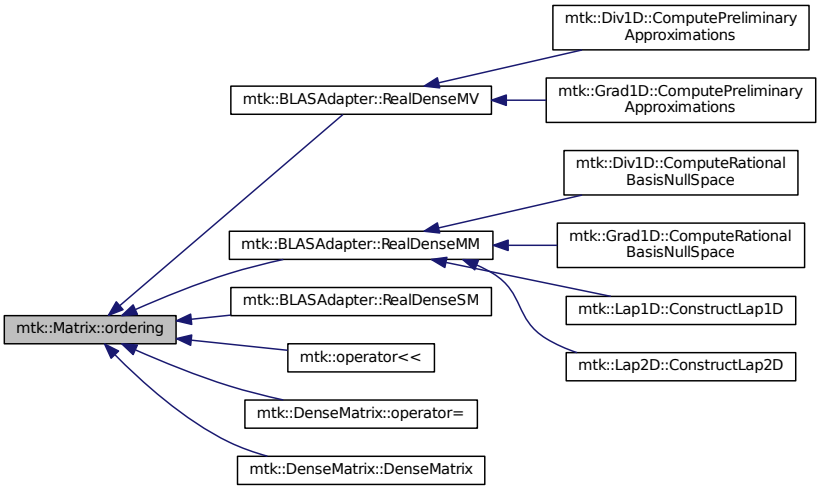

#### 16.17.3.16 mtk::MatrixOrdering mtk::Matrix::ordering ( ) const [noexcept]

**Returns**

Type of ordering of this matrix.

Definition at line 112 of file mtk_matrix.cc.

Here is the caller graph for this function:




#### 16.17.3.17 mtk::Real mtk::Matrix::rel_density ( ) const [noexcept]

**See also**

http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Relative density of the matrix.

Definition at line 172 of file mtk_matrix.cc.

#### 16.17.3.18 mtk::Real mtk::Matrix::rel_sparsity ( ) const [noexcept]

**See also**

http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Relative sparsity of the matrix.

Definition at line 182 of file mtk_matrix.cc.

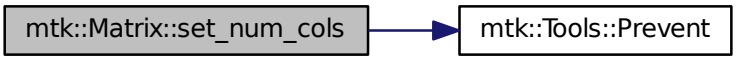
#### 16.17.3.19 void mtk::Matrix::set_num_cols ( const int & *num_cols* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *num_cols* | Number of columns. |

Definition at line 224 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.17.3.20 void mtk::Matrix::set_num_null ( const int & *in* ) [noexcept]

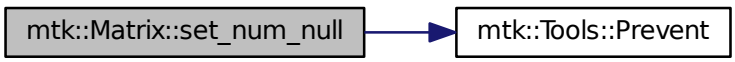
**Parameters**

| | | |
|---|---|---|
| in | *in* | Number of zero values. |

**Bug** -nan assigned on construction time due to num_values_ being 0.

Definition at line 250 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

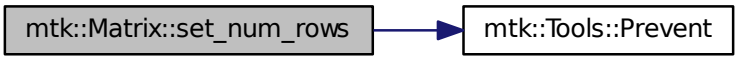

#### 16.17.3.21 void mtk::Matrix::set_num_rows ( const int & *num_rows* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *num_rows* | Number of rows. |

Definition at line 212 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.17.3.22 void mtk::Matrix::set_num_zero ( const int & *in* ) [noexcept]

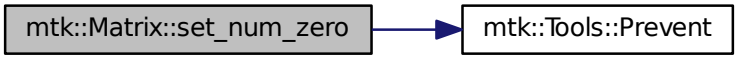
**Parameters**

| | | |
|---|---|---|
| in | *in* | Number of zero values. |

**Bug** -nan assigned on construction time due to num_values_ being 0.

Definition at line 236 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.17.3.23 void mtk::Matrix::set_ordering ( const MatrixOrdering & *oo* ) [noexcept]

**See also**

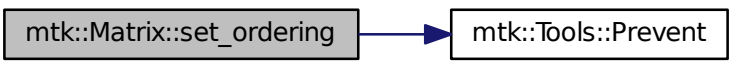
MatrixOrdering

**Parameters**

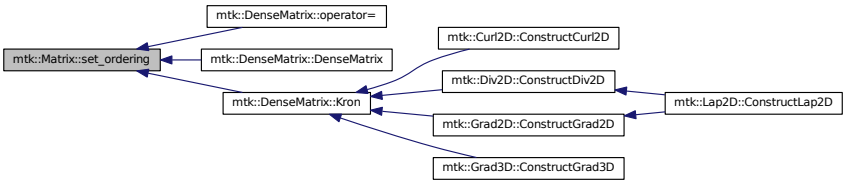
| | | |
|---|---|---|
| in | *oo* | Ordering of the matrix. |

Definition at line 199 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:




#### 16.17.3.24 void mtk::Matrix::set_storage ( const MatrixStorage & *tt* ) [noexcept]

**See also**

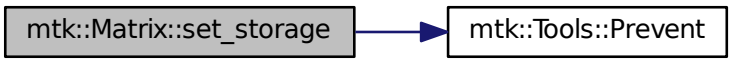
MatrixStorage

**Parameters**

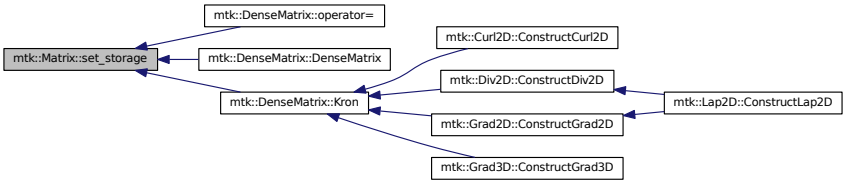
| | | |
|---|---|---|
| in | *tt* | Type of the matrix storage. |

Definition at line 187 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



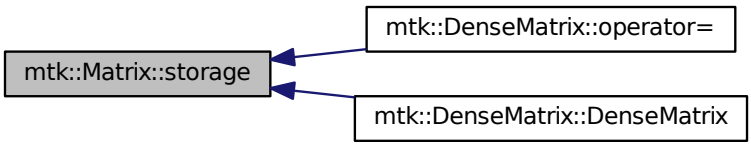

#### 16.17.3.25 mtk::MatrixStorage mtk::Matrix::storage ( ) const [noexcept]

**Returns**

Type of storage of this matrix.

Definition at line 107 of file mtk_matrix.cc.

Here is the caller graph for this function:




### 16.17.4 Member Data Documentation

#### 16.17.4.1 Real mtk::Matrix::abs_density_ [private]

Definition at line 296 of file mtk_matrix.h.

#### 16.17.4.2 Real mtk::Matrix::abs_sparsity_ [private]

Definition at line 298 of file mtk_matrix.h.

#### 16.17.4.3 int mtk::Matrix::bandwidth_ [private]

Definition at line 294 of file mtk_matrix.h.

#### 16.17.4.4 int mtk::Matrix::kl_ [private]

Definition at line 292 of file mtk_matrix.h.

#### 16.17.4.5 int mtk::Matrix::ku_ [private]

Definition at line 293 of file mtk_matrix.h.

#### 16.17.4.6 int mtk::Matrix::ld_ [private]

Definition at line 285 of file mtk_matrix.h.

#### 16.17.4.7 int mtk::Matrix::num_cols_ [private]

Definition at line 283 of file mtk_matrix.h.

#### 16.17.4.8 int mtk::Matrix::num_non_null_ [private]

Definition at line 290 of file mtk_matrix.h.

#### 16.17.4.9 int mtk::Matrix::num_non_zero_ [private]

Definition at line 288 of file mtk_matrix.h.

#### 16.17.4.10 int mtk::Matrix::num_null_ [private]

Definition at line 289 of file mtk_matrix.h.

#### 16.17.4.11 int mtk::Matrix::num_rows_ [private]

Definition at line 282 of file mtk_matrix.h.

#### 16.17.4.12 int mtk::Matrix::num_values_ [private]

Definition at line 284 of file mtk_matrix.h.

#### 16.17.4.13 int mtk::Matrix::num_zero_ [private]

Definition at line 287 of file mtk_matrix.h.

#### 16.17.4.14 MatrixOrdering mtk::Matrix::ordering_ [private]

Definition at line 280 of file mtk_matrix.h.

#### 16.17.4.15 Real mtk::Matrix::rel_density_ [private]

Definition at line 297 of file mtk_matrix.h.

#### 16.17.4.16 Real mtk::Matrix::rel_sparsity_ [private]

Definition at line 299 of file mtk_matrix.h.

#### 16.17.4.17 MatrixStorage mtk::Matrix::storage_ [private]

Definition at line 278 of file mtk_matrix.h.

The documentation for this class was generated from the following files:

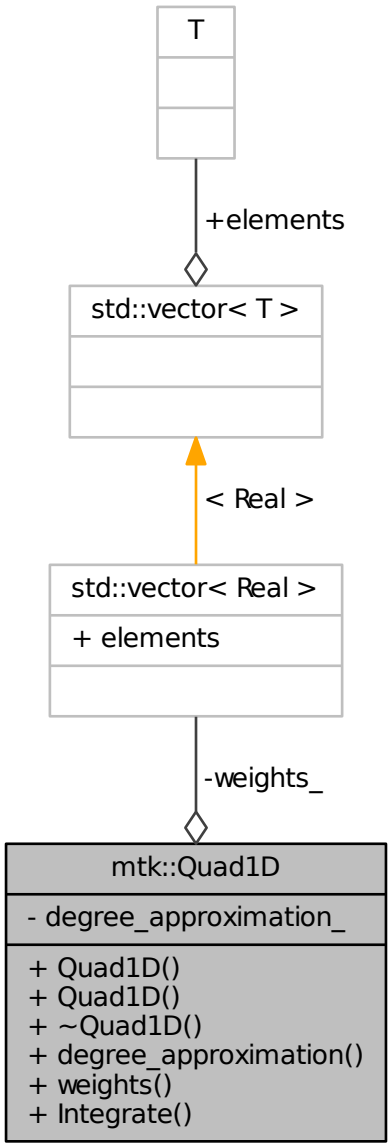
- include/mtk_matrix.h
- src/mtk_matrix.cc

## 16.18 mtk::Quad1D Class Reference

Implements a 1D mimetic quadrature.

`#include <mtk_quad_1d.h>`

Collaboration diagram for mtk::Quad1D:



### Public Member Functions

- Quad1D ()

  *Default constructor.*
- Quad1D (const Quad1D &quad)

  *Copy constructor.*
- ~Quad1D ()

  *Destructor.*
- int degree_approximation () const

  *Get the degree of interpolating polynomial per sub-interval of domain.*
- Real * weights () const

  *Return collection of weights.*
- Real Integrate (Real(*Integrand)(Real xx), UniStgGrid1D grid) const

  *Mimetic integration routine.*

### Private Attributes

- int degree_approximation_

  *Degree of the interpolating polynomial.*
- std::vector< Real > weights_

  *Collection of weights.*

### Friends

- std::ostream & operator<< (std::ostream &stream, Quad1D &in)

  *Output stream operator for printing.*

## 16.18.1 Detailed Description

This class implements a 1D quadrature solver based on the mimetic discretization of the gradient operator.

Definition at line 81 of file mtk_quad_1d.h.

## 16.18.2 Constructor & Destructor Documentation

### 16.18.2.1 mtk::Quad1D::Quad1D ( )

### 16.18.2.2 mtk::Quad1D::Quad1D ( const Quad1D & *quad* )

**Parameters**

| | | |
|---|---|---|
| in | *div* | Given quadrature. |

#### 16.18.2.3 mtk::Quad1D::∼Quad1D ( )

### 16.18.3 Member Function Documentation

#### 16.18.3.1 int mtk::Quad1D::degree_approximation ( ) const

**Returns**

Degree of the interpolating polynomial per sub-interval of the domain.

#### 16.18.3.2 Real mtk::Quad1D::Integrate ( Real(∗)(Real xx) *Integrand,* UniStgGrid1D *grid* ) const

**Parameters**

| | | |
|---|---|---|
| in | *Integrand* | Real-valued function to integrate. |
| in | *grid* | Given integration domain. |

**Returns**

Result of the integration.

#### 16.18.3.3 Real∗ mtk::Quad1D::weights ( ) const

**Returns**

Collection of weights.

### 16.18.4 Friends And Related Function Documentation

#### 16.18.4.1 std::ostream& operator<< ( std::ostream & *stream,* Quad1D & *in* ) [friend]

### 16.18.5 Member Data Documentation

#### 16.18.5.1 int mtk::Quad1D::degree_approximation_ [private]

Definition at line 124 of file mtk_quad_1d.h.

#### 16.18.5.2 std::vector<Real> mtk::Quad1D::weights_ [private]

Definition at line 126 of file mtk_quad_1d.h.

The documentation for this class was generated from the following file:

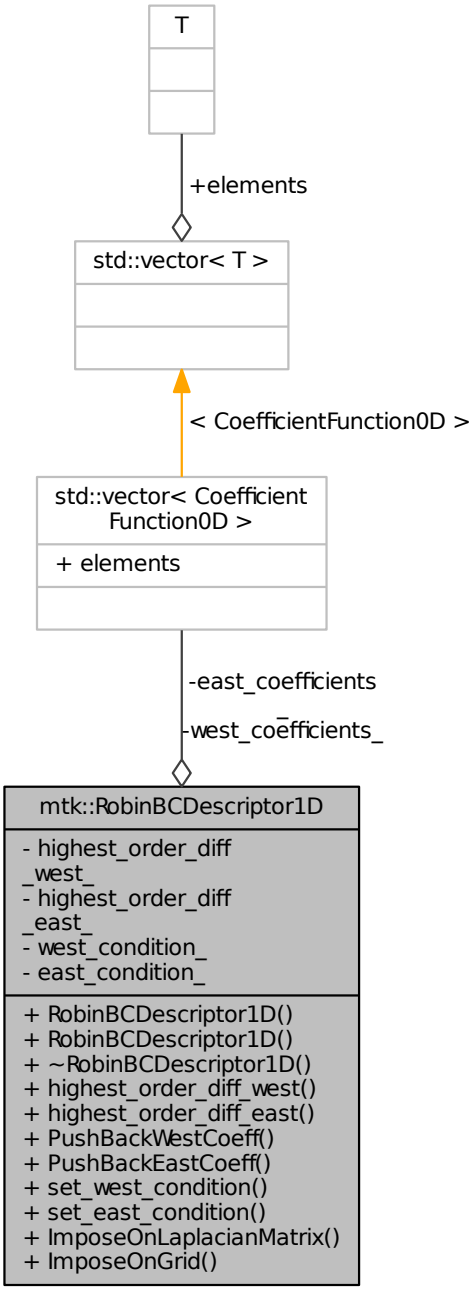
- include/mtk_quad_1d.h

## 16.19 mtk::RobinBCDescriptor1D Class Reference

Impose Robin boundary conditions on the operators and on the grids.

`#include <mtk_robin_bc_descriptor_1d.h>`

Collaboration diagram for mtk::RobinBCDescriptor1D:




## Public Member Functions

- RobinBCDescriptor1D ()

*Default constructor.*

- RobinBCDescriptor1D (const RobinBCDescriptor1D &desc)

  *Copy constructor.*
- ~RobinBCDescriptor1D () noexcept

  *Destructor.*
- int highest_order_diff_west () const noexcept

  *Getter for the highest order of differentiation in the west boundary.*
- int highest_order_diff_east () const noexcept

  *Getter for the highest order of differentiation in the east boundary.*
- void PushBackWestCoeff (CoefficientFunction0D cw)

  *Push back coefficient function at west of lowest order diff. available.*
- void PushBackEastCoeff (CoefficientFunction0D ce)

  *Push back coefficient function at east of lowest order diff. available.*
- void set_west_condition (Real(*west_condition)(const Real &tt)) noexcept

  *Set boundary condition at west.*
- void set_east_condition (Real(*east_condition)(const Real &tt)) noexcept

  *Set boundary condition at east.*
- bool ImposeOnLaplacianMatrix (const Lap1D &lap, DenseMatrix &matrix, const Real &time=mtk::kZero) const

  *Imposes the condition on the operator represented as matrix.*
- void ImposeOnGrid (UniStgGrid1D &grid, const Real &time=mtk::kZero) const

  *Imposes the condition on the grid.*

### Private Attributes

- int highest_order_diff_west_

  *Highest order of differentiation for west.*
- int highest_order_diff_east_

  *Highest order of differentiation for east.*
- std::vector
  < CoefficientFunction0D > west_coefficients_

  *Coeffs. west.*
- std::vector
  < CoefficientFunction0D > east_coefficients_

  *Coeffs. east.*
- Real(* west_condition_ )(const Real &tt)

  *Condition for west.*
- Real(* east_condition_ )(const Real &tt)

  *Condition for east.*

## 16.19.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 1D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

In a 1D context ( $\partial\Omega = \{a,b\} \subset \mathbb{R}$), this condition can be written as follows:

$$\delta_a(a,t)u(a,t) - \eta_a(a,t)u'(a,t) = \beta_a(a,t),$$
$$\delta_b(b,t)u(b,t) + \eta_b(b,t)u'(b,t) = \beta_b(b,t).$$

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

**See also**

http://mathworld.wolfram.com/NormalVector.html

Definition at line 155 of file mtk_robin_bc_descriptor_1d.h.

## 16.19.2 Constructor & Destructor Documentation

### 16.19.2.1 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D ( )

Definition at line 93 of file mtk_robin_bc_descriptor_1d.cc.

### 16.19.2.2 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D ( const RobinBCDescriptor1D & *desc* )

**Parameters**

| | | |
|---|---|---|
| in | *desc* | Given 1D descriptor. |

Definition at line 99 of file mtk_robin_bc_descriptor_1d.cc.

### 16.19.2.3 mtk::RobinBCDescriptor1D::~RobinBCDescriptor1D ( ) [noexcept]

Definition at line 106 of file mtk_robin_bc_descriptor_1d.cc.

## 16.19.3 Member Function Documentation

### 16.19.3.1 int mtk::RobinBCDescriptor1D::highest_order_diff_east ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the east boundary.

Definition at line 113 of file mtk_robin_bc_descriptor_1d.cc.

### 16.19.3.2 int mtk::RobinBCDescriptor1D::highest_order_diff_west ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the west boundary.

Definition at line 108 of file mtk_robin_bc_descriptor_1d.cc.

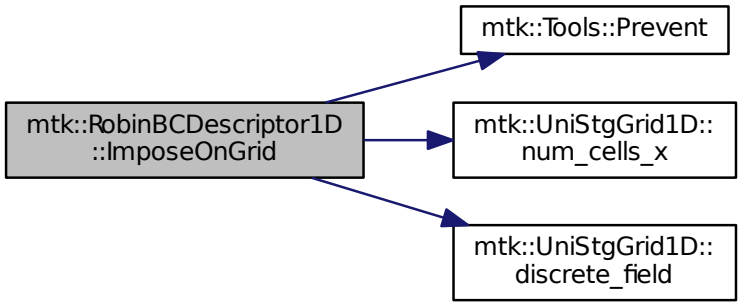
#### 16.19.3.3 void mtk::RobinBCDescriptor1D::ImposeOnGrid ( UniStgGrid1D & *grid*, const Real & *time* = mtk::kZero ) const

**Parameters**

| | | |
|---|---|---|
| in,out | *grid* | Grid upon which impose the desired boundary condition. |
| in | *time* | Current time snapshot. Default is kZero. |

Definition at line 246 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:




#### 16.19.3.4 bool mtk::RobinBCDescriptor1D::ImposeOnLaplacianMatrix ( const Lap1D & *lap*, mtk::DenseMatrix & *matrix*, const Real & *time* = mtk::kZero ) const

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Operator in the Matrix. |
| in,out | *matrix* | Input Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

**Returns**

Success of the imposition.

1. Impose Dirichlet coefficients. 1.1. Impose Dirichlet condition at the west.

1.2. Impose Dirichlet condition at the east.

1. Impose Neumann coefficients.

2.1. Create a mimetic gradient to approximate the first derivative.

2.2. Extract the coefficients approximating the boundary.

**Warning**

Coefficients returned by the mim_bndy getter are dimensionless! Therefore we must scale them by delta_x (from the grid), before adding to the matrix! But this information is in the given lap!

2.3. Impose Neumann condition at the west.

2.3.1. Get gradient coefficient and scale it.

2.3.2. Multiply times the coefficient for this boundary, times the unit normal for this boundary.

2.3.3. Set the final value summing it with what is on the matrix.

2.4. Impose Neumann condition at the east.

**Warning**

The Coefficients returned by the mim_bndy getter are those intended for the west boundary. We must enforce the center-skew-symmetry of the resulting operator by permuting their location in the matrix, and changing their sign.

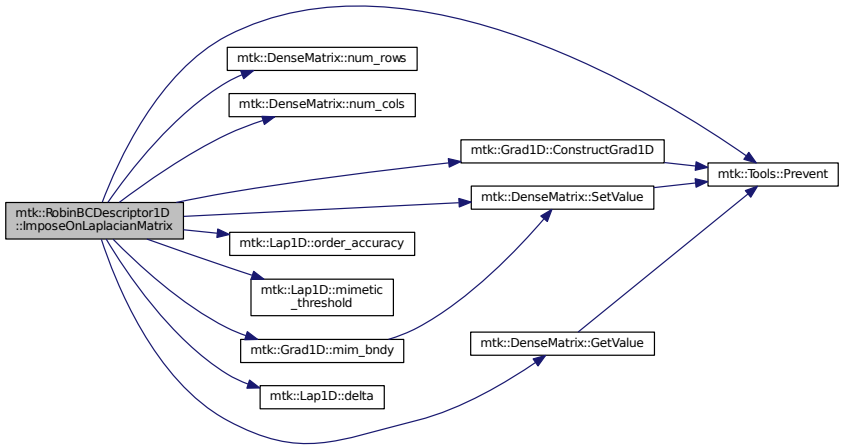
2.4.1. Get gradient coefficient and scale it.

2.4.2. Multiply times the coefficient for this boundary, times the unit normal for this boundary, and change the sign to enforce center-skew-symmetry.

2.4.3. Set the final value summing it with what is on the matrix.

Definition at line 166 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



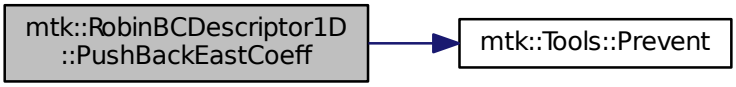

### 16.19.3.5 void mtk::RobinBCDescriptor1D::PushBackEastCoeff ( mtk::CoefficientFunction0D *ce* )

**Parameters**

| | | |
|---|---|---|
| in | *ce* | Function $c_e(x,y) : \Omega \mapsto \mathbb{R}$. |

Definition at line 132 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



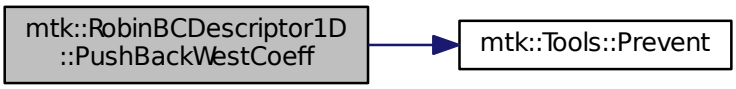

#### 16.19.3.6 void mtk::RobinBCDescriptor1D::PushBackWestCoeff ( mtk::CoefficientFunction0D *cw* )

**Parameters**

| | | |
|---|---|---|
| in | *cw* | Function $c_w(x,y) : \Omega \mapsto \mathbb{R}$. |

Definition at line 118 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



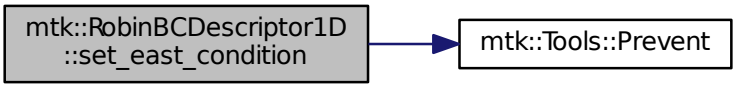

#### 16.19.3.7 void mtk::RobinBCDescriptor1D::set_east_condition ( Real(∗)(const Real &tt) *east_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *east_condition* | $\beta_e(y,t) : \Omega \mapsto \mathbb{R}$. |

Definition at line 156 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



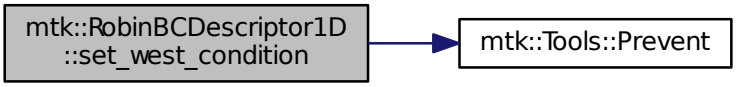

#### 16.19.3.8 void mtk::RobinBCDescriptor1D::set_west_condition ( Real(∗)(const Real &tt) *west_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *west_condition* | $\beta_w(y,t) : \Omega \mapsto \mathbb{R}$. |

Definition at line 146 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:




### 16.19.4 Member Data Documentation

#### 16.19.4.1 std::vector<CoefficientFunction0D> mtk::RobinBCDescriptor1D::east_coefficients_ [private]

Definition at line 237 of file mtk_robin_bc_descriptor_1d.h.

#### 16.19.4.2 Real(∗ mtk::RobinBCDescriptor1D::east_condition_)(const Real &tt) [private]

Definition at line 240 of file mtk_robin_bc_descriptor_1d.h.

#### 16.19.4.3 int mtk::RobinBCDescriptor1D::highest_order_diff_east_ [private]

Definition at line 234 of file mtk_robin_bc_descriptor_1d.h.

#### 16.19.4.4 int mtk::RobinBCDescriptor1D::highest_order_diff_west_ [private]

Definition at line 233 of file mtk_robin_bc_descriptor_1d.h.

#### 16.19.4.5 std::vector<CoefficientFunction0D> mtk::RobinBCDescriptor1D::west_coefficients_ [private]

Definition at line 236 of file mtk_robin_bc_descriptor_1d.h.

#### 16.19.4.6 Real(* mtk::RobinBCDescriptor1D::west_condition_)(const Real &tt) [private]

Definition at line 239 of file mtk_robin_bc_descriptor_1d.h.

The documentation for this class was generated from the following files:

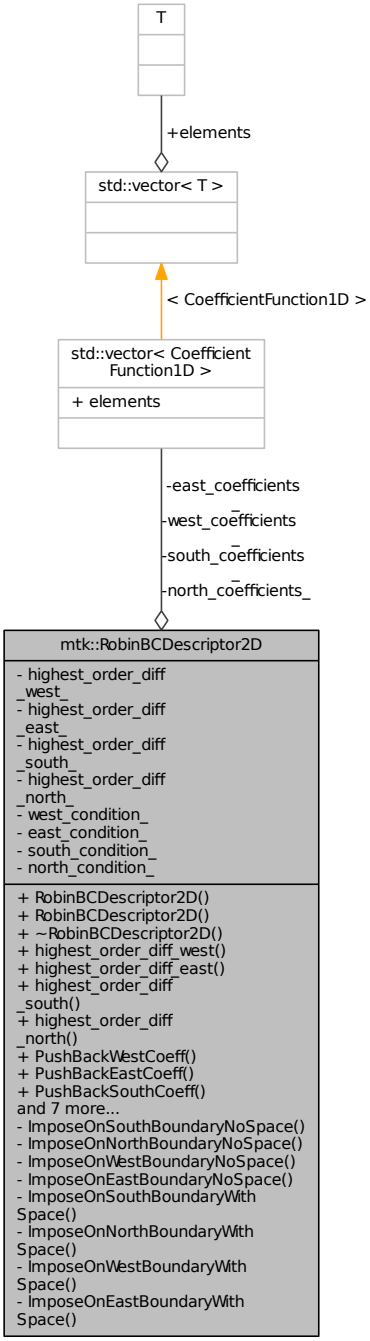
- include/mtk_robin_bc_descriptor_1d.h
- src/mtk_robin_bc_descriptor_1d.cc

## 16.20 mtk::RobinBCDescriptor2D Class Reference

Impose Robin boundary conditions on the operators and on the grids.

`#include <mtk_robin_bc_descriptor_2d.h>`

Collaboration diagram for mtk::RobinBCDescriptor2D:




## Public Member Functions

- RobinBCDescriptor2D ()

*Default constructor.*

- RobinBCDescriptor2D (const RobinBCDescriptor2D &desc)

  *Copy constructor.*
- ~RobinBCDescriptor2D () noexcept

  *Destructor.*
- int highest_order_diff_west () const noexcept

  *Getter for the highest order of differentiation in the west boundary.*
- int highest_order_diff_east () const noexcept

  *Getter for the highest order of differentiation in the east boundary.*
- int highest_order_diff_south () const noexcept

  *Getter for the highest order of differentiation in the south boundary.*
- int highest_order_diff_north () const noexcept

  *Getter for the highest order of differentiation in the north boundary.*
- void PushBackWestCoeff (CoefficientFunction1D cw)

  *Push back coefficient function at west of lowest order diff. available.*
- void PushBackEastCoeff (CoefficientFunction1D ce)

  *Push back coefficient function at east of lowest order diff. available.*
- void PushBackSouthCoeff (CoefficientFunction1D cs)

  *Push back coefficient function south of lowest order diff. available.*
- void PushBackNorthCoeff (CoefficientFunction1D cn)

  *Push back coefficient function north of lowest order diff. available.*
- void set_west_condition (Real(*west_condition)(const Real &yy, const Real &tt)) noexcept

  *Set boundary condition at west.*
- void set_east_condition (Real(*east_condition)(const Real &yy, const Real &tt)) noexcept

  *Set boundary condition at east.*
- void set_south_condition (Real(*south_condition)(const Real &xx, const Real &tt)) noexcept

  *Set boundary condition at south.*
- void set_north_condition (Real(*north_condition)(const Real &xx, const Real &tt)) noexcept

  *Set boundary condition at north.*
- bool ImposeOnLaplacianMatrix (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the operator represented as matrix.*
- void ImposeOnGrid (UniStgGrid2D &grid, const Real &time=kZero) const

  *Imposes the condition on the grid.*

## Private Member Functions

- bool ImposeOnSouthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the south boundary.*
- bool ImposeOnNorthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the north boundary.*
- bool ImposeOnWestBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the west boundary.*
- bool ImposeOnEastBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

*Imposes the condition on the east boundary.*

- bool ImposeOnSouthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the south boundary.*

- bool ImposeOnNorthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the north boundary.*

- bool ImposeOnWestBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the west boundary.*

- bool ImposeOnEastBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  *Imposes the condition on the east boundary.*

## Private Attributes

- int highest_order_diff_west_

  *Highest order of differentiation west.*

- int highest_order_diff_east_

  *Highest order of differentiation east.*

- int highest_order_diff_south_

  *Highest order differentiation for south.*

- int highest_order_diff_north_

  *Highest order differentiation for north.*

- std::vector < CoefficientFunction1D > west_coefficients_

  *Coeffs. west.*

- std::vector < CoefficientFunction1D > east_coefficients_

  *Coeffs. east.*

- std::vector < CoefficientFunction1D > south_coefficients_

  *Coeffs. south.*

- std::vector < CoefficientFunction1D > north_coefficients_

  *Coeffs. south.*

- Real(* west_condition_ )(const Real &xx, const Real &tt)

  *Condition west.*

- Real(* east_condition_ )(const Real &xx, const Real &tt)

  *Condition east.*

- Real(* south_condition_ )(const Real &yy, const Real &tt)

  *Cond. south.*

- Real(* north_condition_ )(const Real &yy, const Real &tt)

  *Cond. north.*

### 16.20.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

**See also**

http://mathworld.wolfram.com/NormalVector.html

Definition at line 132 of file mtk_robin_bc_descriptor_2d.h.

### 16.20.2 Constructor & Destructor Documentation

#### 16.20.2.1 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D ( )

Definition at line 84 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.2.2 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D ( const RobinBCDescriptor2D & *desc* )

**Parameters**

| | | |
|---|---|---|
| in | *desc* | Given 2D descriptor. |

Definition at line 94 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.2.3 mtk::RobinBCDescriptor2D::~RobinBCDescriptor2D ( ) [noexcept]

Definition at line 105 of file mtk_robin_bc_descriptor_2d.cc.

### 16.20.3 Member Function Documentation

#### 16.20.3.1 int mtk::RobinBCDescriptor2D::highest_order_diff_east ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the east boundary.

Definition at line 112 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.3.2 int mtk::RobinBCDescriptor2D::highest_order_diff_north ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the north boundary.

Definition at line 122 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.3.3 int mtk::RobinBCDescriptor2D::highest_order_diff_south ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the south boundary.

Definition at line 117 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.3.4 int mtk::RobinBCDescriptor2D::highest_order_diff_west ( ) const [noexcept]

**Returns**

Integer highest order of differentiation in the west boundary.

Definition at line 107 of file mtk_robin_bc_descriptor_2d.cc.

#### 16.20.3.5 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryNoSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

**Parameters**

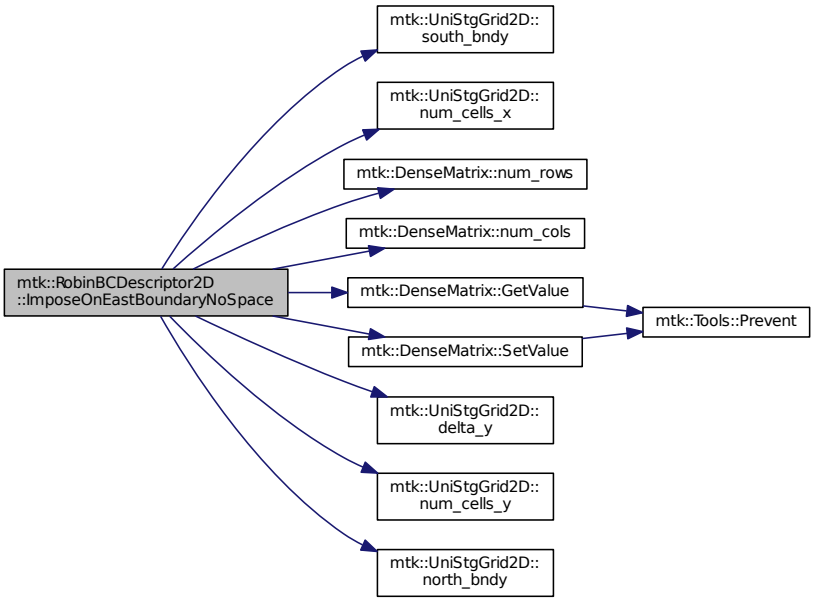
| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

Definition at line 495 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




### 16.20.3.6 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryWithSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

**Parameters**

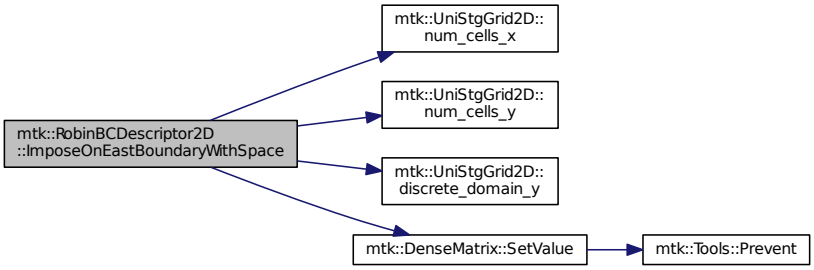
| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

Definition at line 564 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




#### 16.20.3.7 void mtk::RobinBCDescriptor2D::ImposeOnGrid ( mtk::UniStgGrid2D & *grid,* const Real & *time* = kZero ) const

**Parameters**

| | | |
|---|---|---|
| in,out | *grid* | Grid upon which impose the desired boundary condition. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose assuming an scalar grid.

1.1. Impose south condition.

1.1.1. Impose south-west corner.

1.1.2. Impose south border.

1.1.3. Impose south-east corner.

1.2. Impose north condition.

1.2.1. Impose north-west corner.

1.2.2. Impose north border.

1.2.3. Impose north-east corner.

1.3. Impose west condition.

1.3.1. Impose south-west corner.

**Note**

As per discussion with Otilio, we will take the **arithmetic mean** of the values of the BCs at the corners.

1.3.2. Impose west border.

1.3.3. Impose north-west corner.

1.4. Impose east condition.

1.4.1. Impose south-east corner.

1.4.2. Impose east border.

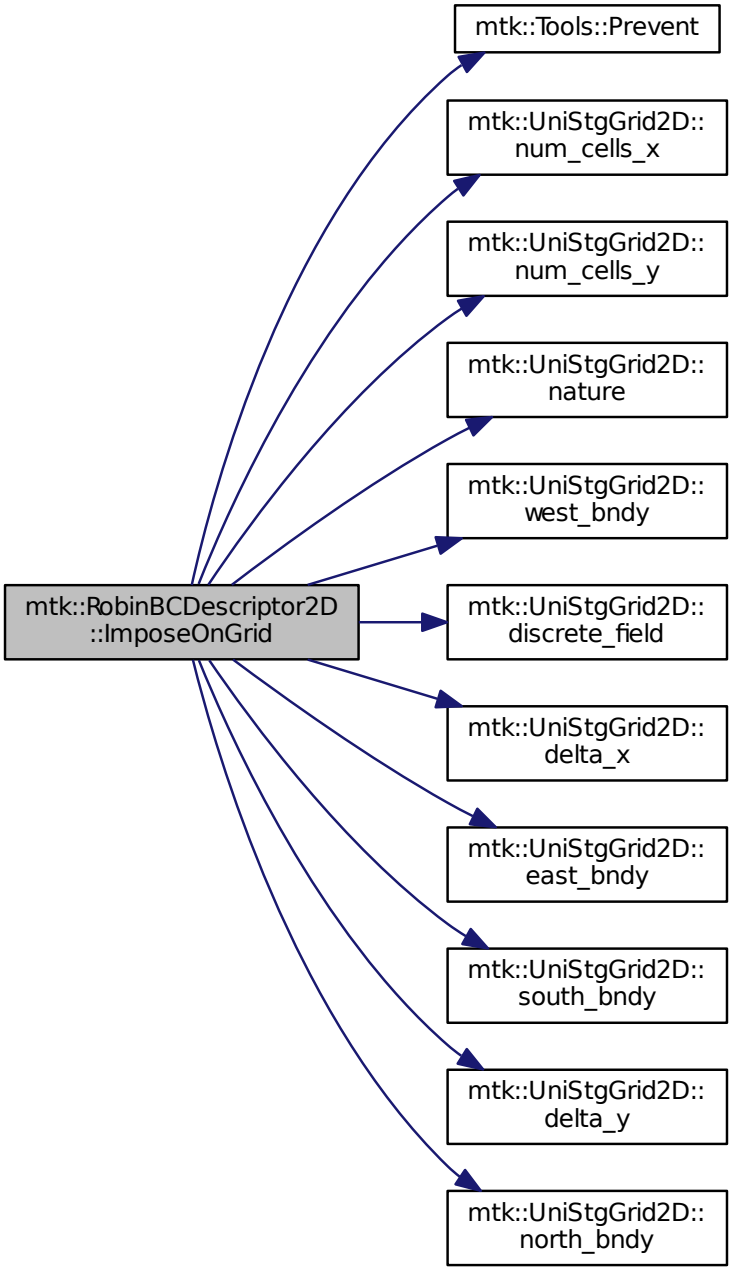
1.4.3. Impose north-east corner.

1. Impose assuming a vector grid.

**Todo** Implement imposition for vector-valued grids. Need research here!

Definition at line 674 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



#### 16.20.3.8 bool mtk::RobinBCDescriptor2D::ImposeOnLaplacianMatrix ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const

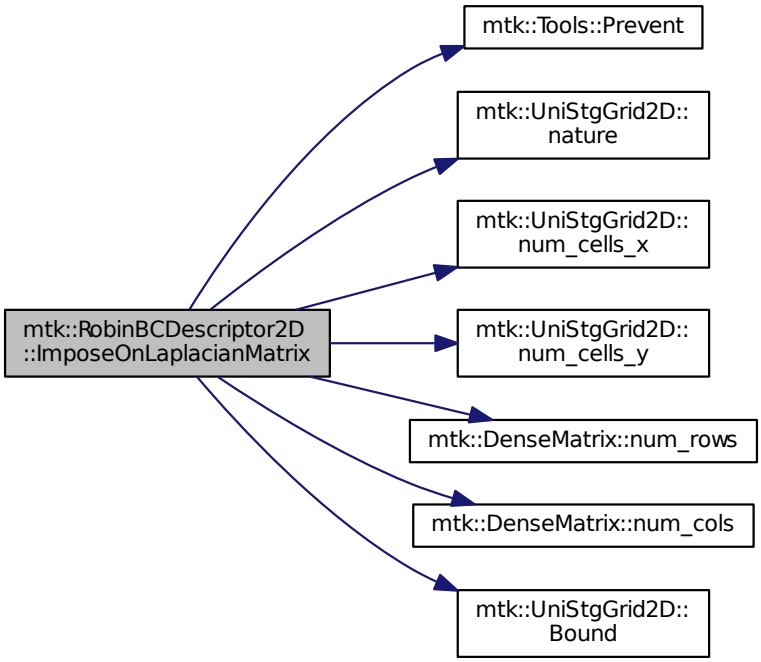
**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

If we have not bound anything to the grid, then we have to generate our collection of spatial coordinates, as we evaluate the coefficients.

Definition at line 591 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




#### 16.20.3.9 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryNoSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

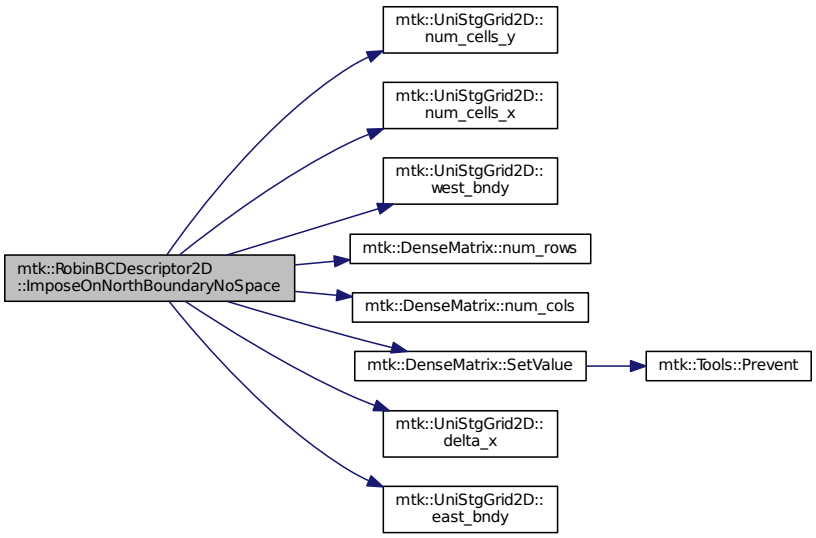
**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition.

Definition at line 312 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




### 16.20.3.10 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryWithSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose Dirichlet condition.

For each entry on the diagonal:

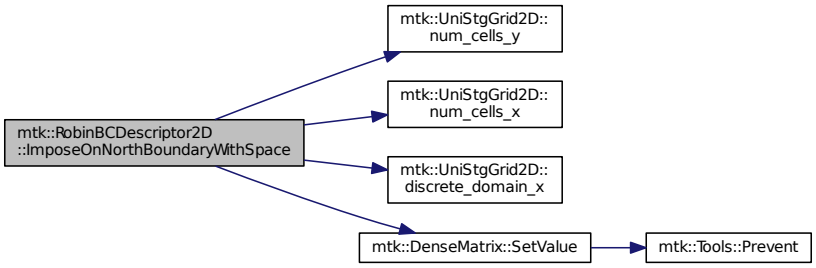
Evaluate next set spatial coordinates to evaluate the coefficient.

Evaluate and assign the Dirichlet coefficient.

1. Impose the Neumann condition.

Definition at line 372 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




#### 16.20.3.11 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryNoSpace ( const Lap2D & *lap,* const UniStgGrid2D & *grid,* mtk::DenseMatrix & *matrix,* const Real & *time* = kZero ) const [private]

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

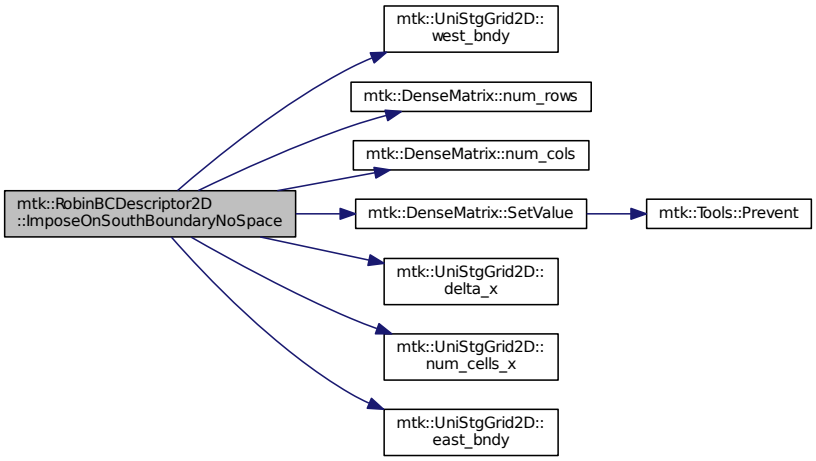
1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

**Todo** Impose the Neumann conditions on every pole, for every scenario.

Definition at line 229 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




#### 16.20.3.12 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryWithSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

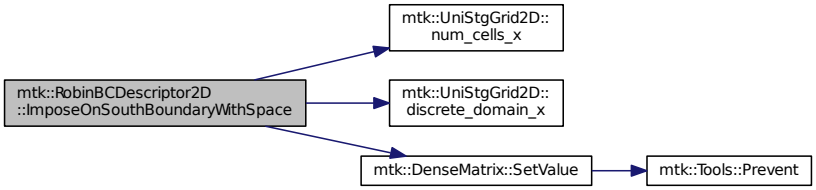
1. Impose the Dirichlet condition first.

**Todo** Impose Harmonic mean on the corners for the case when the generated space is available, for all poles.

1. Impose the Neumann condition.

Definition at line 284 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



#### 16.20.3.13 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryNoSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose the Dirichlet condition first.

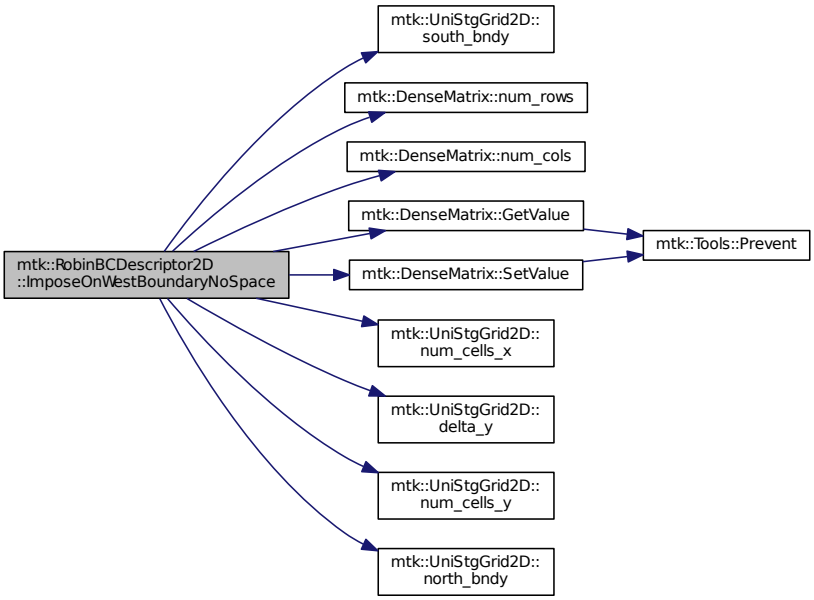
**Note**

As it can be seen, we must adopt a convention about how to treat the corners. Based on a reasoning with Otilio, we will take the **harmonic mean**.

1. Impose the Neumann condition.

Definition at line 399 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




#### 16.20.3.14 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryWithSpace ( const Lap2D & *lap*, const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const Real & *time* = kZero ) const [private]

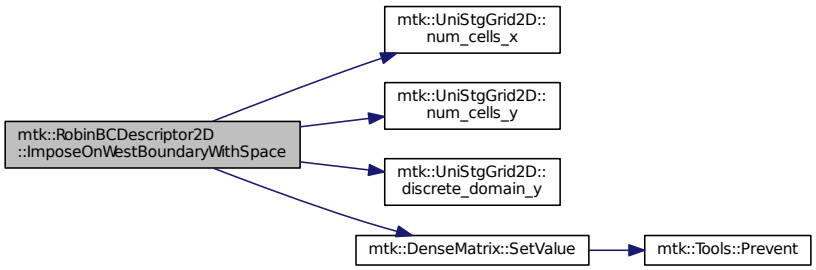
**Parameters**

| | | |
|---|---|---|
| in | *lap* | Laplacian operator on the matrix. |
| in | *grid* | Grid upon which impose the desired boundary condition. |
| in,out | *matrix* | Input matrix with the Laplacian operator. |
| in | *time* | Current time snapshot. Default is kZero. |

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition.

Definition at line 468 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



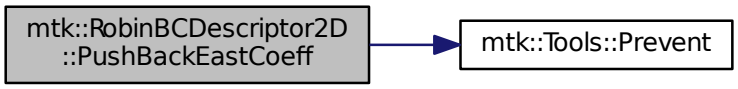

#### 16.20.3.15 void mtk::RobinBCDescriptor2D::PushBackEastCoeff ( mtk::CoefficientFunction1D *ce* )

**Parameters**

| | | |
|---|---|---|
| in | *cw* | Coeff. $c_e(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 141 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



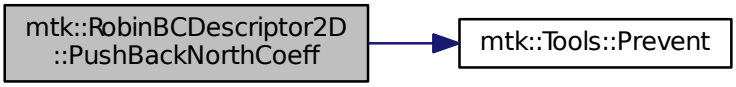

#### 16.20.3.16 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff ( mtk::CoefficientFunction1D *cn* )

**Parameters**

| | | |
|---|---|---|
| in | *cw* | Coeff. $c_n(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 169 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



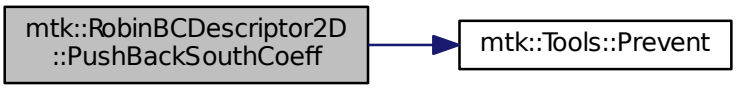

#### 16.20.3.17 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff ( mtk::CoefficientFunction1D *cs* )

**Parameters**

| | | |
|---|---|---|
| in | *cw* | Coeff. $c_s(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 155 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



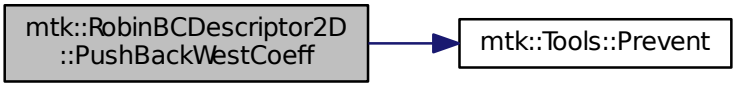

#### 16.20.3.18 void mtk::RobinBCDescriptor2D::PushBackWestCoeff ( mtk::CoefficientFunction1D *cw* )

**Parameters**

| | | |
|---|---|---|
| in | *cw* | Coeff. $c_w(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 127 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



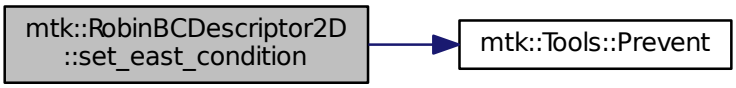

#### 16.20.3.19 void mtk::RobinBCDescriptor2D::set_east_condition ( Real(∗)(const Real &yy, const Real &tt) *east_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *east_condition* | $\beta_e(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 194 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



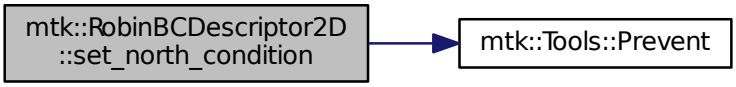

#### 16.20.3.20 void mtk::RobinBCDescriptor2D::set_north_condition ( Real(∗)(const Real &xx, const Real &tt) *north_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *north_condition* | $\beta_n(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 217 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



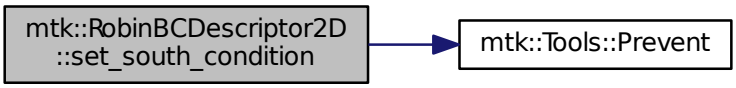

#### 16.20.3.21 void mtk::RobinBCDescriptor2D::set_south_condition ( Real(∗)(const Real &xx, const Real &tt) *south_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *south_condition* | $\beta_s(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 205 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



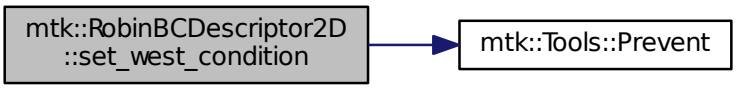

#### 16.20.3.22 void mtk::RobinBCDescriptor2D::set_west_condition ( Real(∗)(const Real &yy, const Real &tt) *west_condition* ) [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *west_condition* | $\beta_w(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$. |

Definition at line 183 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:




### 16.20.4 Member Data Documentation

#### 16.20.4.1 std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::east_coefficients_ [private]

Definition at line 367 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.2 Real(* mtk::RobinBCDescriptor2D::east_condition_)(const Real &xx, const Real &tt) [private]

Definition at line 372 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.3 int mtk::RobinBCDescriptor2D::highest_order_diff_east_ [private]

Definition at line 362 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.4 int mtk::RobinBCDescriptor2D::highest_order_diff_north_ [private]

Definition at line 364 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.5 int mtk::RobinBCDescriptor2D::highest_order_diff_south_ [private]

Definition at line 363 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.6 int mtk::RobinBCDescriptor2D::highest_order_diff_west_ [private]

Definition at line 361 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.7 std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::north_coefficients_ [private]

Definition at line 369 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.8 Real(* mtk::RobinBCDescriptor2D::north_condition_)(const Real &yy, const Real &tt) [private]

Definition at line 374 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.9 std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::south_coefficients_ [private]

Definition at line 368 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.10 Real(* mtk::RobinBCDescriptor2D::south_condition_)(const Real &yy, const Real &tt) [private]

Definition at line 373 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.11 std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::west_coefficients_ [private]

Definition at line 366 of file mtk_robin_bc_descriptor_2d.h.

#### 16.20.4.12 Real(* mtk::RobinBCDescriptor2D::west_condition_)(const Real &xx, const Real &tt) [private]

Definition at line 371 of file mtk_robin_bc_descriptor_2d.h.

The documentation for this class was generated from the following files:

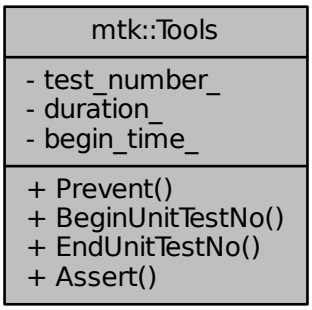
- include/mtk_robin_bc_descriptor_2d.h
- src/mtk_robin_bc_descriptor_2d.cc

## 16.21 mtk::Tools Class Reference

Tool manager class.

`#include <mtk_tools.h>`

Collaboration diagram for mtk::Tools:




### Static Public Member Functions

- static void Prevent (const bool complement, const char *const fname, int lineno, const char *const fxname) noexcept

*Enforces preconditions by preventing their complements from occur.*

- static void BeginUnitTestNo (const int &nn) noexcept

  *Begins the execution of a unit test. Starts a timer.*
- static void EndUnitTestNo (const int &nn) noexcept

  *Ends the execution of a unit test. Stops and reports wall-clock time.*
- static void Assert (const bool &condition) noexcept

  *Asserts if the condition required to pass the unit test occurs.*

### Static Private Attributes

- static int test_number_

  *Current test being executed.*
- static Real duration_

  *Duration of the current test.*
- static clock_t begin_time_

  *Elapsed time on current test.*

## 16.21.1 Detailed Description

Basic tools to ensure execution correctness.

Definition at line 78 of file mtk_tools.h.

## 16.21.2 Member Function Documentation

### 16.21.2.1 void mtk::Tools::Assert ( const bool & *condition* ) [static], [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *condition* | Condition to be asserted. |

Definition at line 109 of file mtk_tools.cc.

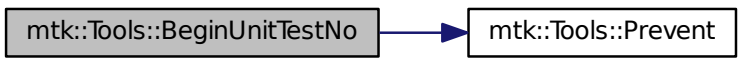
### 16.21.2.2 void mtk::Tools::BeginUnitTestNo ( const int & *nn* ) [static], [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *nn* | Number of the test. |

Definition at line 88 of file mtk_tools.cc.

Here is the call graph for this function:



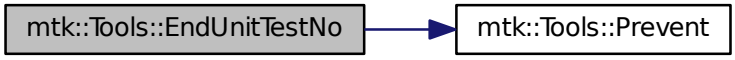
#### 16.21.2.3 void mtk::Tools::EndUnitTestNo ( const int & *nn* ) [static], [noexcept]

**Parameters**

| | | |
|---|---|---|
| in | *nn* | Number of the test. |

Definition at line 100 of file mtk_tools.cc.

Here is the call graph for this function:




#### 16.21.2.4 void mtk::Tools::Prevent ( const bool *complement*, const char *const *fname*, int *lineno*, const char *const *fxname* ) [static], [noexcept]

**See also**

http://stackoverflow.com/questions/8884335/print-the-file-name-line-number-and-function

**Parameters**

| | | |
|---|---|---|
| in | *complement* | Complement of desired pre-condition. |
| in | *fname* | Name of the file being checked. |
| in | *lineno* | Number of the line where the check is executed. |
| in | *fxname* | Name of the module containing the check. |

**Todo** Check if this is the best way of stalling execution.

Definition at line 61 of file mtk_tools.cc.

### 16.21.3 Member Data Documentation

#### 16.21.3.1 clock_t mtk::Tools::begin_time_ [static], [private]

Definition at line 121 of file mtk_tools.h.

#### 16.21.3.2 mtk::Real mtk::Tools::duration_ [static], [private]

Definition at line 119 of file mtk_tools.h.

#### 16.21.3.3 int mtk::Tools::test_number_ [static], [private]

**Todo** Check usage of static methods and private members.

Definition at line 117 of file mtk_tools.h.

The documentation for this class was generated from the following files:

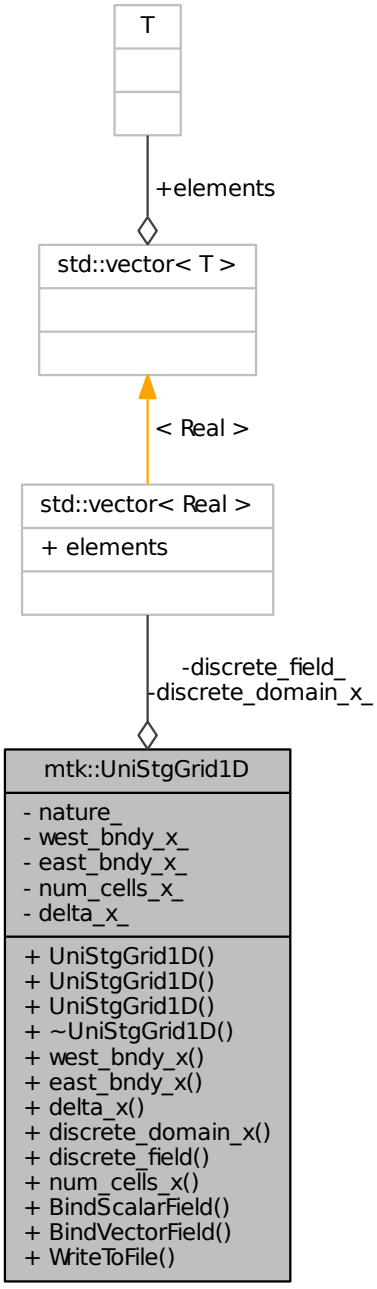
- include/mtk_tools.h
- src/mtk_tools.cc

## 16.22 mtk::UniStgGrid1D Class Reference

Uniform 1D Staggered Grid.

`#include <mtk_uni_stg_grid_1d.h>`

Collaboration diagram for mtk::UniStgGrid1D:




## Public Member Functions

- UniStgGrid1D ()

*Default constructor.*

- UniStgGrid1D (const UniStgGrid1D &grid)

  *Copy constructor.*
- UniStgGrid1D (const Real &west_bndy_x, const Real &east_bndy_x, const int &num_cells_x, const mtk::FieldNature &nature=mtk::SCALAR)

  *Construct a grid based on spatial discretization parameters.*
- ~UniStgGrid1D ()

  *Destructor.*
- Real west_bndy_x () const

  *Provides access to west boundary spatial coordinate.*
- Real east_bndy_x () const

  *Provides access to east boundary spatial coordinate.*
- Real delta_x () const

  *Provides access to the computed $ x $.*
- const Real * discrete_domain_x () const

  *Provides access to the grid spatial data.*
- Real * discrete_field ()

  *Provides access to the grid field data.*
- int num_cells_x () const

  *Provides access to the number of cells of the grid.*
- void BindScalarField (Real(*ScalarField)(const Real &xx))

  *Binds a given scalar field to the grid.*
- void BindVectorField (Real(*VectorField)(Real xx))

  *Binds a given vector field to the grid.*
- bool WriteToFile (std::string filename, std::string space_name, std::string field_name) const

  *Writes grid to a file compatible with gnuplot 4.6.*

## Private Attributes

- FieldNature nature_

  *Nature of the discrete field.*
- std::vector< Real > discrete_domain_x_

  *Array of spatial data.*
- std::vector< Real > discrete_field_

  *Array of field's data.*
- Real west_bndy_x_

  *West boundary spatial coordinate.*
- Real east_bndy_x_

  *East boundary spatial coordinate.*
- Real num_cells_x_

  *Number of cells discretizing the domain.*
- Real delta_x_

  *Produced $\Delta x$.*

## Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid1D &in)

  *Prints the grid as a tuple of arrays.*

### 16.22.1 Detailed Description

Uniform 1D Staggered Grid.

Definition at line 77 of file mtk_uni_stg_grid_1d.h.

### 16.22.2 Constructor & Destructor Documentation

#### 16.22.2.1 mtk::UniStgGrid1D::UniStgGrid1D ( )

Definition at line 99 of file mtk_uni_stg_grid_1d.cc.

#### 16.22.2.2 mtk::UniStgGrid1D::UniStgGrid1D ( const UniStgGrid1D & *grid* )

**Parameters**

| | | |
|---|---|---|
| in | *grid* | Given grid. |

Definition at line 108 of file mtk_uni_stg_grid_1d.cc.

#### 16.22.2.3 mtk::UniStgGrid1D::UniStgGrid1D ( const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const mtk::FieldNature & *nature* = mtk::SCALAR )

**Parameters**

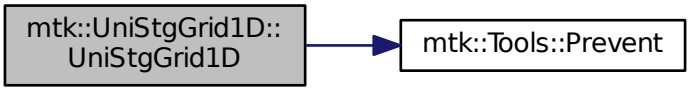
| | | |
|---|---|---|
| in | *west_bndy_x* | Coordinate for the west boundary. |
| in | *east_bndy_x* | Coordinate for the east boundary. |
| in | *num_cells_x* | Number of cells of the required grid. |
| in | *nature* | Nature of the discrete field to hold. |

**See also**

mtk::FieldNature

Definition at line 124 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:




#### 16.22.2.4 mtk::UniStgGrid1D::~UniStgGrid1D ( )

Definition at line 144 of file mtk_uni_stg_grid_1d.cc.

### 16.22.3 Member Function Documentation

#### 16.22.3.1 void mtk::UniStgGrid1D::BindScalarField ( Real(∗)(const Real &xx) *ScalarField* )

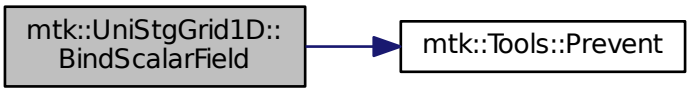
**Parameters**

| | | |
|---|---|---|
| in | *ScalarField* | Pointer to the function implementing the scalar field. |

1. Create collection of spatial coordinates.
2. Create collection of field samples.

Definition at line 176 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:




#### 16.22.3.2 void mtk::UniStgGrid1D::BindVectorField ( Real(∗)(Real xx) *VectorField* )

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = v(x)\hat{\mathbf{i}}$$

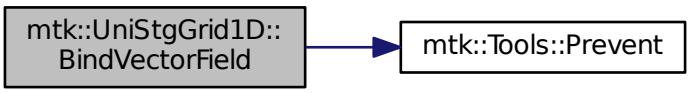
**Parameters**

| | | |
|---|---|---|
| in | *VectorField* | Pointer to the function implementing the vector field. |

1. Create collection of spatial coordinates.
2. Create collection of field samples.

Definition at line 212 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



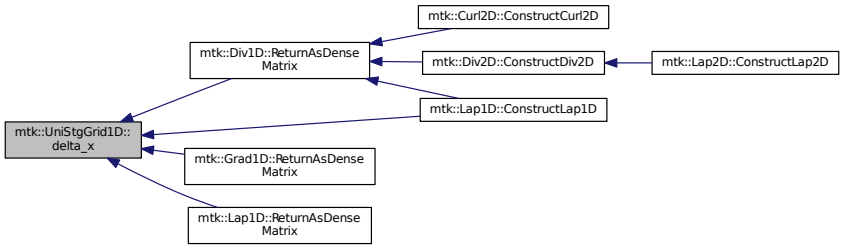
#### 16.22.3.3 mtk::Real mtk::UniStgGrid1D::delta_x ( ) const

**Returns**

Computed $ x $.

Definition at line 156 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:




#### 16.22.3.4 const mtk::Real * mtk::UniStgGrid1D::discrete_domain_x ( ) const

**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 161 of file mtk_uni_stg_grid_1d.cc.

#### 16.22.3.5 mtk::Real * mtk::UniStgGrid1D::discrete_field ( )

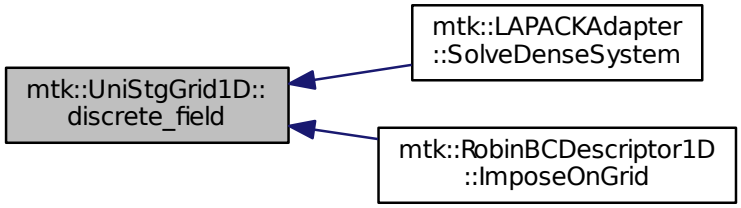
**Returns**

Pointer to the field data.

**Todo** Review const-correctness of the pointer we return. Look at the STL!

Definition at line 166 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:




#### 16.22.3.6 mtk::Real mtk::UniStgGrid1D::east_bndy_x ( ) const

**Returns**

East boundary spatial coordinate.

Definition at line 151 of file mtk_uni_stg_grid_1d.cc.

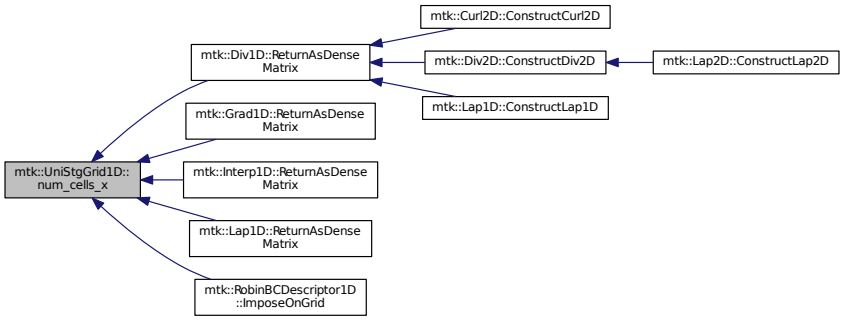
#### 16.22.3.7 int mtk::UniStgGrid1D::num_cells_x ( ) const

**Returns**

Number of cells of the grid.

Definition at line 171 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:




#### 16.22.3.8 mtk::Real mtk::UniStgGrid1D::west_bndy_x ( ) const

**Returns**

West boundary spatial coordinate.

Definition at line 146 of file mtk_uni_stg_grid_1d.cc.

#### 16.22.3.9 bool mtk::UniStgGrid1D::WriteToFile ( std::string *filename*, std::string *space_name*, std::string *field_name* ) const

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |
| in | *space_name* | Name for the first column of the data. |
| in | *field_name* | Name for the second column of the data. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Definition at line 240 of file mtk_uni_stg_grid_1d.cc.

### 16.22.4 Friends And Related Function Documentation

#### 16.22.4.1 std::ostream& operator<< ( std::ostream & *stream*, mtk::UniStgGrid1D & *in* ) [friend]

1. Print spatial coordinates.

2. Print scalar field.

Definition at line 68 of file mtk_uni_stg_grid_1d.cc.

### 16.22.5 Member Data Documentation

#### 16.22.5.1 Real mtk::UniStgGrid1D::delta_x_ [private]

Definition at line 199 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.2 std::vector<Real> mtk::UniStgGrid1D::discrete_domain_x_ [private]

Definition at line 193 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.3 std::vector<Real> mtk::UniStgGrid1D::discrete_field_ [private]

Definition at line 194 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.4 Real mtk::UniStgGrid1D::east_bndy_x_ [private]

Definition at line 197 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.5 FieldNature mtk::UniStgGrid1D::nature_ [private]

Definition at line 191 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.6 Real mtk::UniStgGrid1D::num_cells_x_ [private]

Definition at line 198 of file mtk_uni_stg_grid_1d.h.

#### 16.22.5.7 Real mtk::UniStgGrid1D::west_bndy_x_ [private]

Definition at line 196 of file mtk_uni_stg_grid_1d.h.

The documentation for this class was generated from the following files:

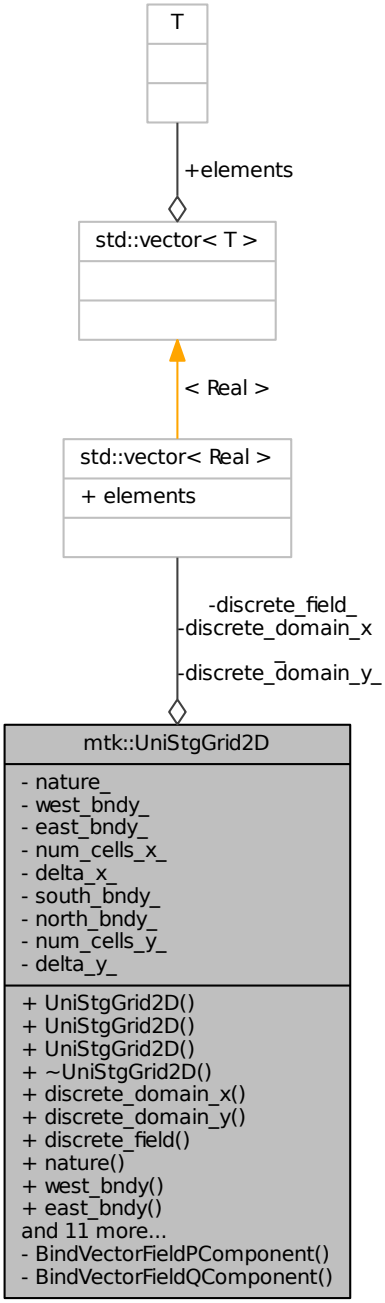
- include/mtk_uni_stg_grid_1d.h
- src/mtk_uni_stg_grid_1d.cc

## 16.23 mtk::UniStgGrid2D Class Reference

Uniform 2D Staggered Grid.

`#include <mtk_uni_stg_grid_2d.h>`

Collaboration diagram for mtk::UniStgGrid2D:




## Public Member Functions

- UniStgGrid2D ()

*Default constructor.*

- UniStgGrid2D (const UniStgGrid2D &grid)

  *Copy constructor.*

- UniStgGrid2D (const Real &west_bndy_x, const Real &east_bndy_x, const int &num_cells_x, const Real &south_bndy_y, const Real &north_bndy_y, const int &num_cells_y, const mtk::FieldNature &nature=mtk::SCALAR)

  *Construct a grid based on spatial discretization parameters.*

- ~UniStgGrid2D ()

  *Destructor.*

- const Real * discrete_domain_x () const

  *Provides access to the grid spatial data.*

- const Real * discrete_domain_y () const

  *Provides access to the grid spatial data.*

- Real * discrete_field ()

  *Provides access to the grid field data.*

- FieldNature nature () const

  *Physical nature of the data bound to the grid.*

- Real west_bndy () const

  *Provides access to west boundary spatial coordinate.*

- Real east_bndy () const

  *Provides access to east boundary spatial coordinate.*

- int num_cells_x () const

  *Provides access to the number of cells of the grid.*

- Real delta_x () const

  *Provides access to the computed $ x $.*

- Real south_bndy () const

  *Provides access to south boundary spatial coordinate.*

- Real north_bndy () const

  *Provides access to north boundary spatial coordinate.*

- int num_cells_y () const

  *Provides access to the number of cells of the grid.*

- Real delta_y () const

  *Provides access to the computed $ y $.*

- bool Bound () const

  *Have any field been bound to the grid?*

- int Size () const

  *Total number of samples in the grid.*

- void BindScalarField (Real(*ScalarField)(const Real &xx, const Real &yy))

  *Binds a given scalar field to the grid.*

- void BindVectorField (Real(*VectorFieldPComponent)(const Real &xx, const Real &yy), Real(*VectorFieldQComponent)(const Real &xx, const Real &yy))

  *Binds a given vector field to the grid.*

- bool WriteToFile (std::string filename, std::string space_name_x, std::string space_name_y, std::string field_name) const

  *Writes grid to a file compatible with Gnuplot 4.6.*

### Private Member Functions

- void BindVectorFieldPComponent (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy))

  *Binds a given component of a vector field to the grid.*
- void BindVectorFieldQComponent (Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy))

  *Binds a given component of a vector field to the grid.*

### Private Attributes

- std::vector< Real > discrete_domain_x_

  *Array of spatial data.*
- std::vector< Real > discrete_domain_y_

  *Array of spatial data.*
- std::vector< Real > discrete_field_

  *Array of field's data.*
- FieldNature nature_

  *Nature of the discrete field.*
- Real west_bndy_

  *West boundary spatial coordinate.*
- Real east_bndy_

  *East boundary spatial coordinate.*
- int num_cells_x_

  *Number of cells discretizing the domain.*
- Real delta_x_

  *Computed $\Delta x$.*
- Real south_bndy_

  *West boundary spatial coordinate.*
- Real north_bndy_

  *East boundary spatial coordinate.*
- int num_cells_y_

  *Number of cells discretizing the domain.*
- Real delta_y_

  *Computed $\Delta y$.*

### Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid2D &in)

  *Prints the grid as a tuple of arrays.*

#### 16.23.1 Detailed Description

Uniform 2D Staggered Grid.

Definition at line 79 of file mtk_uni_stg_grid_2d.h.

## 16.23.2 Constructor & Destructor Documentation

### 16.23.2.1 mtk::UniStgGrid2D::UniStgGrid2D ( )

Definition at line 131 of file mtk_uni_stg_grid_2d.cc.

### 16.23.2.2 mtk::UniStgGrid2D::UniStgGrid2D ( const UniStgGrid2D & *grid* )

**Parameters**

| | | |
|---|---|---|
| in | *grid* | Given grid. |

Definition at line 145 of file mtk_uni_stg_grid_2d.cc.

### 16.23.2.3 mtk::UniStgGrid2D::UniStgGrid2D ( const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const Real & *south_bndy_y*, const Real & *north_bndy_y*, const int & *num_cells_y*, const mtk::FieldNature & *nature* = mtk::SCALAR )

**Parameters**

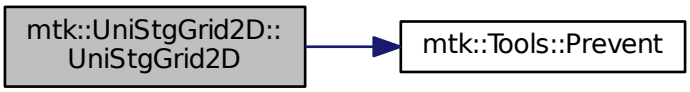
| | | |
|---|---|---|
| in | *west_bndy_x* | Coordinate for the west boundary. |
| in | *east_bndy_x* | Coordinate for the east boundary. |
| in | *num_cells_x* | Number of cells of the required grid. |
| in | *south_bndy_y* | Coordinate for the west boundary. |
| in | *north_bndy_y* | Coordinate for the east boundary. |
| in | *num_cells_y* | Number of cells of the required grid. |
| in | *nature* | Nature of the discrete field to hold. |

**See also**

mtk::FieldNature

Definition at line 169 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:




### 16.23.2.4 mtk::UniStgGrid2D::~UniStgGrid2D ( )

Definition at line 203 of file mtk_uni_stg_grid_2d.cc.

### 16.23.3 Member Function Documentation

#### 16.23.3.1 void mtk::UniStgGrid2D::BindScalarField ( Real(∗)(const Real &xx, const Real &yy) *ScalarField* )

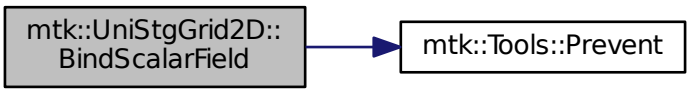
**Parameters**

| | | |
|---|---|---|
| in | *ScalarField* | Pointer to the function implementing the scalar field. |

1. Create collection of spatial coordinates for $x$.
2. Create collection of spatial coordinates for $y$.
3. Create collection of field samples.

Definition at line 275 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:




#### 16.23.3.2 void mtk::UniStgGrid2D::BindVectorField ( Real(∗)(const Real &xx, const Real &yy) *VectorFieldPComponent*, Real(∗)(const Real &xx, const Real &yy) *VectorFieldQComponent* )

We assume the field to be of the form:

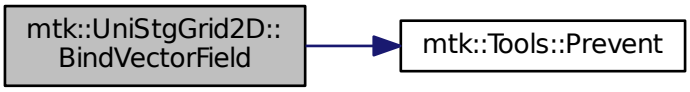
$$\mathbf{v}(\mathbf{x}) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

**Parameters**

| | | |
|---|---|---|
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ p $ component of the vector field. |
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ q $ component of the vector field. |

Definition at line 423 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:




#### 16.23.3.3 void mtk::UniStgGrid2D::BindVectorFieldPComponent ( Real(*)(const Real &xx, const Real &yy) *VectorFieldPComponent* ) [private]

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

**Parameters**

| | | |
|---|---|---|
| in | *BindVectorField↩ PComponent* | Pointer to the function implementing the $ p $ component of the vector field. |

1. Create collection of spatial coordinates for $x$.
2. Create collection of spatial coordinates for $y$.
3. Allocate space for discrete vector field and bind $ p $ component.

Definition at line 330 of file mtk_uni_stg_grid_2d.cc.

#### 16.23.3.4 void mtk::UniStgGrid2D::BindVectorFieldQComponent ( Real(*)(const Real &xx, const Real &yy) *VectorFieldQComponent* ) [private]

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

**Parameters**

| | | |
|---|---|---|
| in | *BindVectorField↩ QComponent* | Pointer to the function implementing the $ q $ component of the vector field. |

1. Bind $ q $ component, since $ p $ component has already been bound.

Definition at line 395 of file mtk_uni_stg_grid_2d.cc.

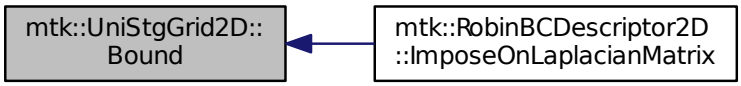
#### 16.23.3.5 bool mtk::UniStgGrid2D::Bound ( ) const

**Returns**

True is a field has been bound.

Definition at line 255 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



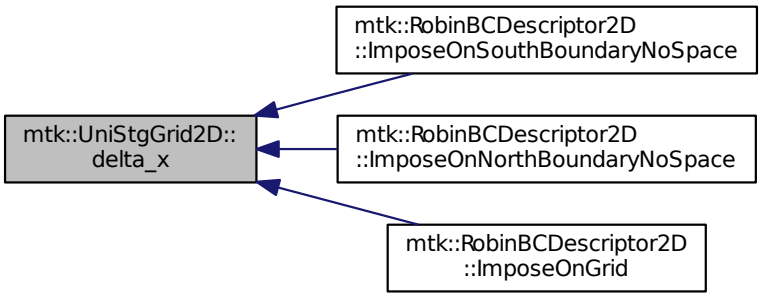

#### 16.23.3.6 mtk::Real mtk::UniStgGrid2D::delta_x ( ) const

**Returns**

Computed $ x $.

Definition at line 225 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



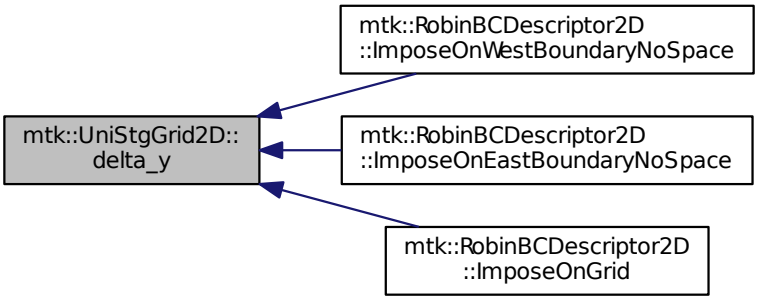

#### 16.23.3.7 mtk::Real mtk::UniStgGrid2D::delta_y ( ) const

**Returns**

Computed $ y $.

Definition at line 250 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:




#### 16.23.3.8 const mtk::Real * mtk::UniStgGrid2D::discrete_domain_x ( ) const

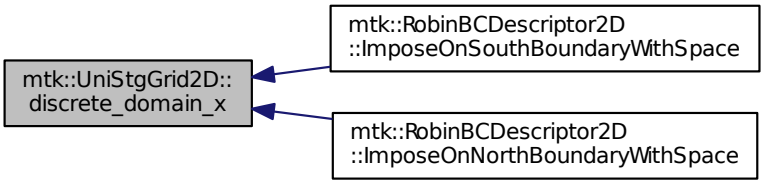
**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 230 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:




#### 16.23.3.9 const mtk::Real * mtk::UniStgGrid2D::discrete_domain_y ( ) const

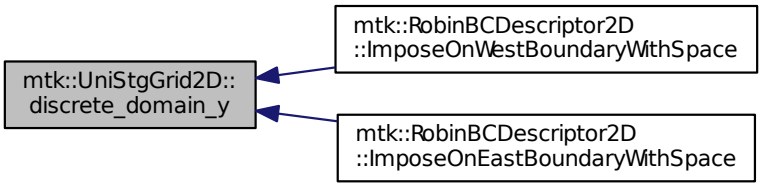
**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 260 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



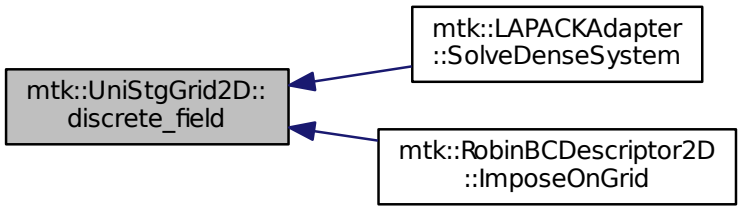

#### 16.23.3.10 mtk::Real * mtk::UniStgGrid2D::discrete_field ( )

**Returns**

Pointer to the field data.

Definition at line 265 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



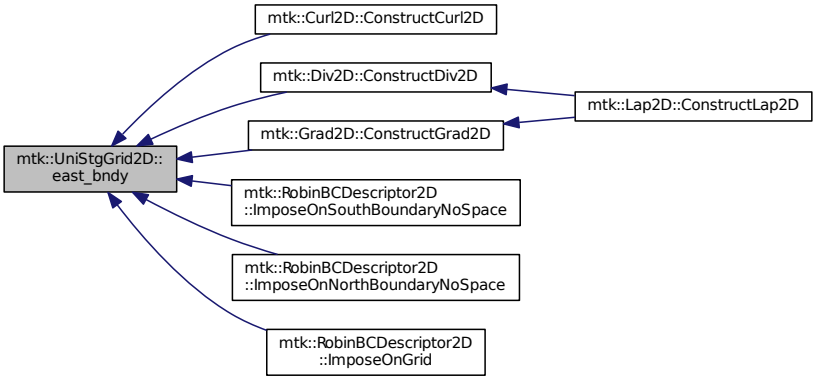

#### 16.23.3.11 mtk::Real mtk::UniStgGrid2D::east_bndy ( ) const

**Returns**

East boundary spatial coordinate.

Definition at line 215 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:




#### 16.23.3.12 mtk::FieldNature mtk::UniStgGrid2D::nature ( ) const

**Returns**

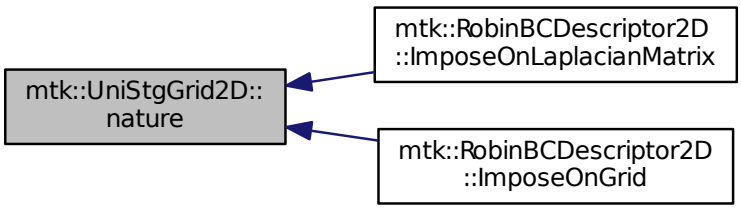
Value of an enumeration.

**See also**

mtk::FieldNature

Definition at line 205 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



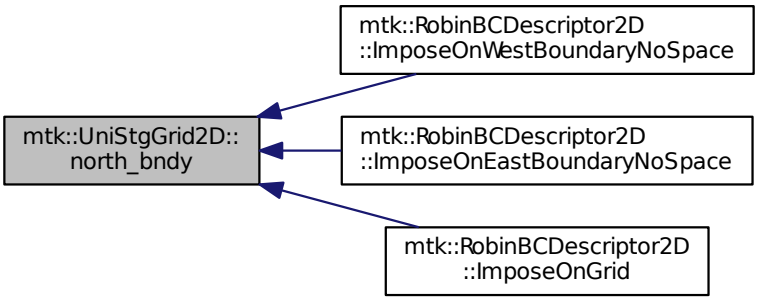
#### 16.23.3.13 mtk::Real mtk::UniStgGrid2D::north_bndy ( ) const

**Returns**

North boundary spatial coordinate.

Definition at line 240 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



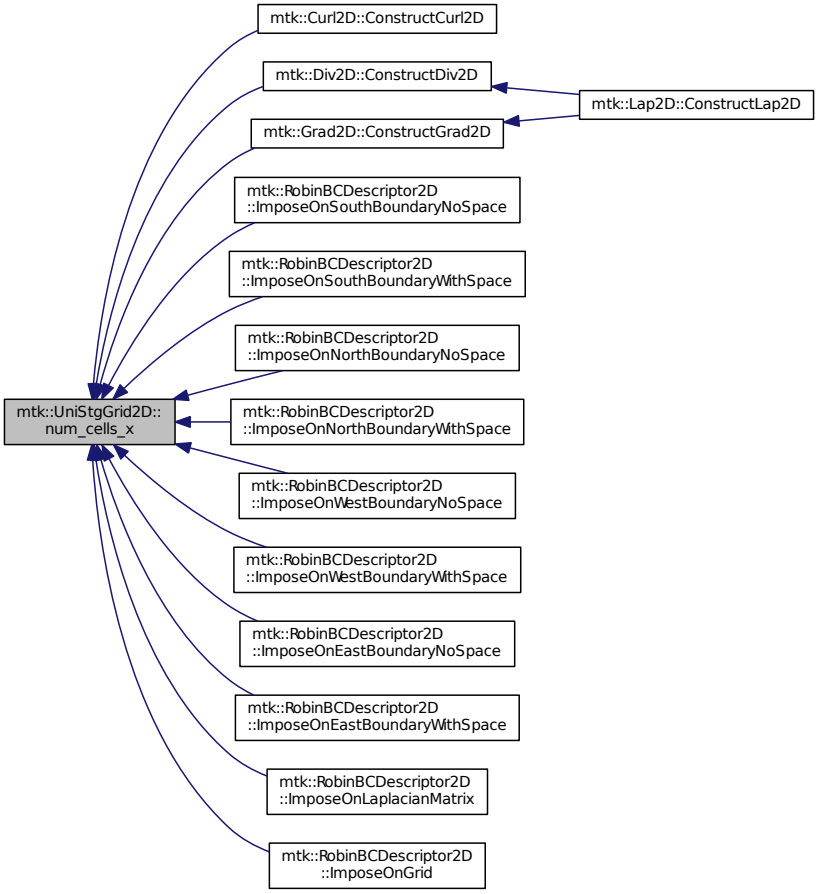

#### 16.23.3.14 int mtk::UniStgGrid2D::num_cells_x ( ) const

**Returns**

Number of cells of the grid.

Definition at line 220 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



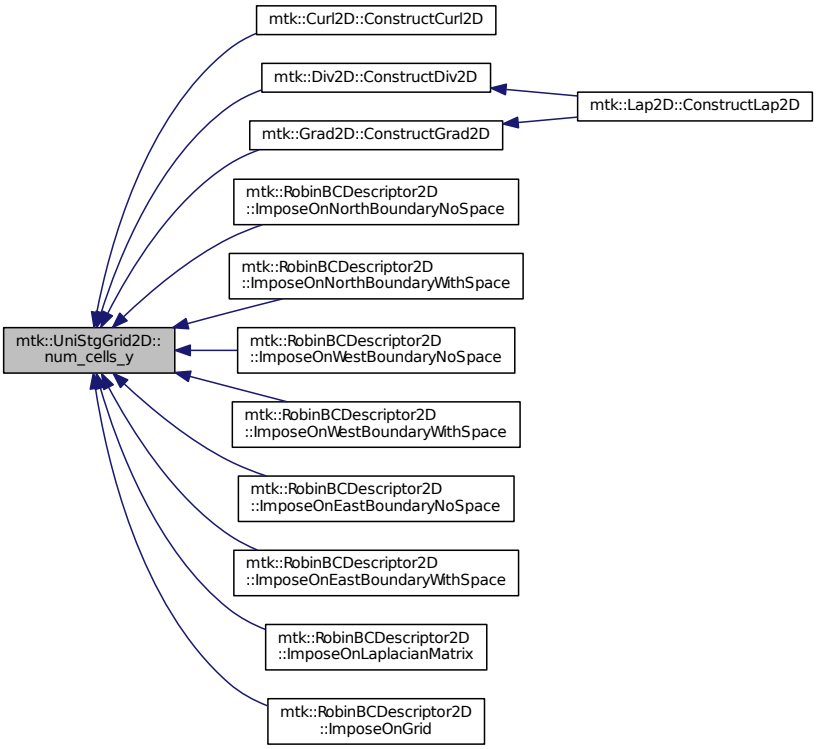

#### 16.23.3.15 int mtk::UniStgGrid2D::num_cells_y ( ) const

**Returns**

Number of cells of the grid.

Definition at line 245 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:




#### 16.23.3.16 int mtk::UniStgGrid2D::Size ( ) const

**Returns**

Total number of samples in the grid.

Definition at line 270 of file mtk_uni_stg_grid_2d.cc.

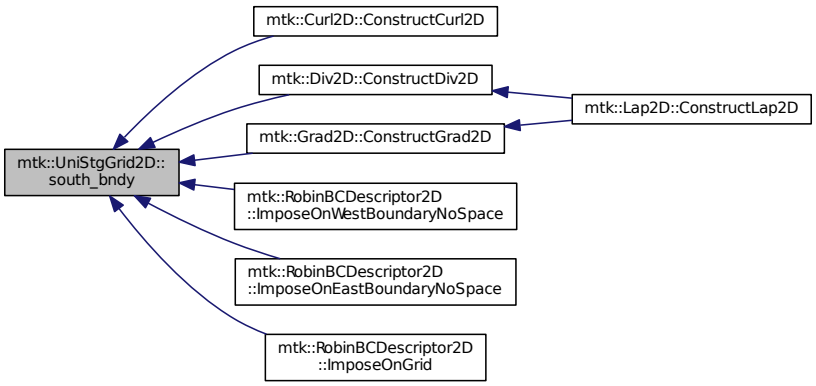
#### 16.23.3.17 mtk::Real mtk::UniStgGrid2D::south_bndy ( ) const

**Returns**

South boundary spatial coordinate.

Definition at line 235 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



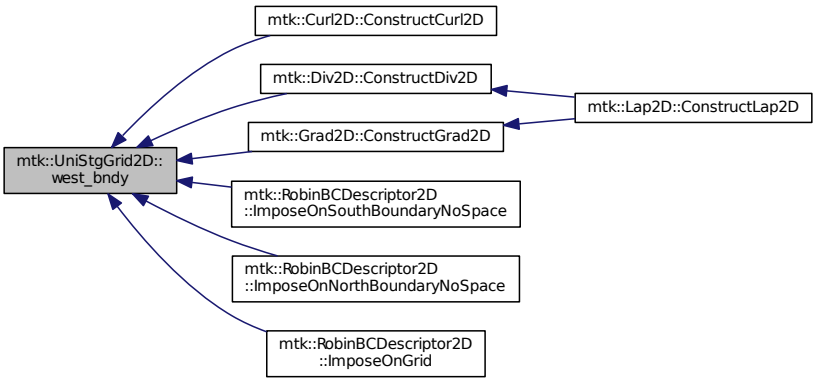

#### 16.23.3.18 mtk::Real mtk::UniStgGrid2D::west_bndy ( ) const

**Returns**

West boundary spatial coordinate.

Definition at line 210 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



16.23.3.19 bool mtk::UniStgGrid2D::WriteToFile ( std::string *filename,* std::string *space_name_x,* std::string *space_name_y,* std::string *field_name* ) const

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |
| in | *space_name_x* | Name for the first column of the (spatial) data. |
| in | *space_name_y* | Name for the second column of the (spatial) data. |
| in | *field_name* | Name for the second column of the (physical field) data. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Write the values of the p component, with a null q component.

Write the values of the q component, with a null p component.

Definition at line 435 of file mtk_uni_stg_grid_2d.cc.

### 16.23.4 Friends And Related Function Documentation

#### 16.23.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::UniStgGrid2D & *in* ) [friend]

1. Print spatial coordinates.
2. Print scalar field.

Definition at line 67 of file mtk_uni_stg_grid_2d.cc.

### 16.23.5 Member Data Documentation

#### 16.23.5.1 Real mtk::UniStgGrid2D::delta_x_ [private]

Definition at line 302 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.2 Real mtk::UniStgGrid2D::delta_y_ [private]

Definition at line 307 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.3 std::vector<Real> mtk::UniStgGrid2D::discrete_domain_x_ [private]

Definition at line 293 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.4 std::vector<Real> mtk::UniStgGrid2D::discrete_domain_y_ [private]

Definition at line 294 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.5 std::vector<Real> mtk::UniStgGrid2D::discrete_field_ [private]

Definition at line 295 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.6 Real mtk::UniStgGrid2D::east_bndy_ [private]

Definition at line 300 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.7 FieldNature mtk::UniStgGrid2D::nature_ [private]

Definition at line 297 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.8 Real mtk::UniStgGrid2D::north_bndy_ [private]

Definition at line 305 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.9 int mtk::UniStgGrid2D::num_cells_x_ [private]

Definition at line 301 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.10 int mtk::UniStgGrid2D::num_cells_y_ [private]

Definition at line 306 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.11 Real mtk::UniStgGrid2D::south_bndy_ [private]

Definition at line 304 of file mtk_uni_stg_grid_2d.h.

#### 16.23.5.12 Real mtk::UniStgGrid2D::west_bndy_ [private]

Definition at line 299 of file mtk_uni_stg_grid_2d.h.

The documentation for this class was generated from the following files:

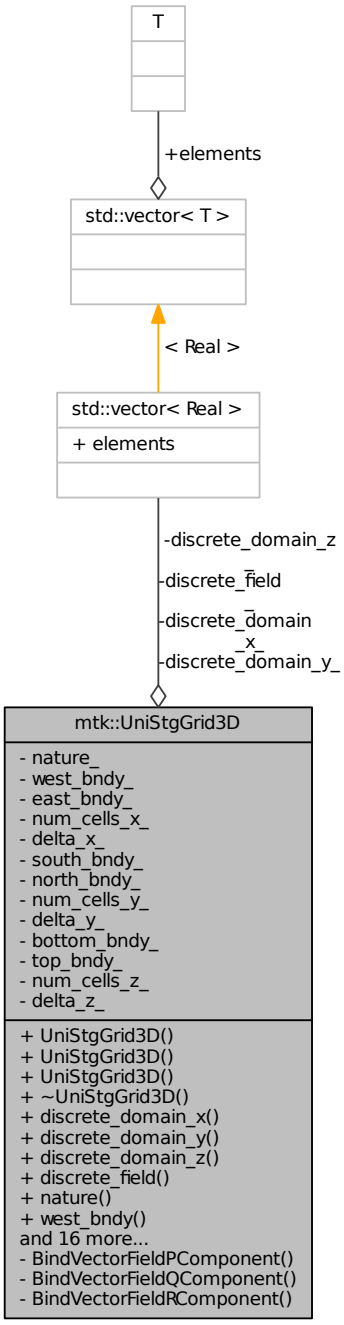
- include/mtk_uni_stg_grid_2d.h
- src/mtk_uni_stg_grid_2d.cc

## 16.24 mtk::UniStgGrid3D Class Reference

Uniform 3D Staggered Grid.

`#include <mtk_uni_stg_grid_3d.h>`

Collaboration diagram for mtk::UniStgGrid3D:




## Public Member Functions

- UniStgGrid3D ()

*Default constructor.*

- UniStgGrid3D (const UniStgGrid3D &grid)

  *Copy constructor.*

- UniStgGrid3D (const Real &west_bndy_x, const Real &east_bndy_x, const int &num_cells_x, const Real &south_bndy_y, const Real &north_bndy_y, const int &num_cells_y, const Real &bottom_bndy_z, const Real &top_bndy_z, const int &num_cells_z, const mtk::FieldNature &nature=mtk::SCALAR)

  *Construct a grid based on spatial discretization parameters.*

- ~UniStgGrid3D ()

  *Destructor.*

- const Real * discrete_domain_x () const

  *Provides access to the grid spatial data.*

- const Real * discrete_domain_y () const

  *Provides access to the grid spatial data.*

- const Real * discrete_domain_z () const

  *Provides access to the grid spatial data.*

- Real * discrete_field ()

  *Provides access to the grid field data.*

- FieldNature nature () const

  *Physical nature of the data bound to the grid.*

- Real west_bndy () const

  *Provides access to west boundary spatial coordinate.*

- Real east_bndy () const

  *Provides access to east boundary spatial coordinate.*

- int num_cells_x () const

  *Provides access to the number of cells of the grid.*

- Real delta_x () const

  *Provides access to the computed $ x $.*

- Real south_bndy () const

  *Provides access to south boundary spatial coordinate.*

- Real north_bndy () const

  *Provides access to north boundary spatial coordinate.*

- int num_cells_y () const

  *Provides access to the number of cells of the grid.*

- Real delta_y () const

  *Provides access to the computed $ y $.*

- Real bottom_bndy () const

  *Provides access to bottom boundary spatial coordinate.*

- Real top_bndy () const

  *Provides access to top boundary spatial coordinate.*

- int num_cells_z () const

  *Provides access to the number of cells of the grid.*

- Real delta_z () const

  *Provides access to the computed $ z $.*

- bool Bound () const

  *Have any field been bound to the grid?*

- int Size () const

  *Total number of samples in the grid.*

- void BindScalarField (Real(∗ScalarField)(const Real &xx, const Real &yy, const Real &zz))

  *Binds a given scalar field to the grid.*
- void BindVectorField (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy, const Real &zz), Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy, const Real &zz), Real(∗VectorFieldR↩ Component)(const Real &xx, const Real &yy, const Real &zz))

  *Binds a given vector field to the grid.*
- bool WriteToFile (std::string filename, std::string space_name_x, std::string space_name_y, std::string space_↩ name_z, std::string field_name) const

  *Writes grid to a file compatible with Gnuplot 4.6.*

### Private Member Functions

- void BindVectorFieldPComponent (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy, const Real &zz))

  *Binds a given component of a vector field to the grid.*
- void BindVectorFieldQComponent (Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy, const Real &zz))

  *Binds a given component of a vector field to the grid.*
- void BindVectorFieldRComponent (Real(∗VectorFieldRComponent)(const Real &xx, const Real &yy, const Real &zz))

  *Binds a given component of a vector field to the grid.*

### Private Attributes

- std::vector< Real > discrete_domain_x_

  *Array of spatial data.*
- std::vector< Real > discrete_domain_y_

  *Array of spatial data.*
- std::vector< Real > discrete_domain_z_

  *Array of spatial data.*
- std::vector< Real > discrete_field_

  *Array of field's data.*
- FieldNature nature_

  *Nature of the discrete field.*
- Real west_bndy_

  *West boundary spatial coordinate.*
- Real east_bndy_

  *East boundary spatial coordinate.*
- int num_cells_x_

  *Number of cells discretizing the domain.*
- Real delta_x_

  *Computed $\Delta x$.*
- Real south_bndy_

  *West boundary spatial coordinate.*
- Real north_bndy_

  *East boundary spatial coordinate.*
- int num_cells_y_

*Number of cells discretizing the domain.*

- Real delta_y_

  *Computed $\Delta y$.*

- Real bottom_bndy_

  *Bottom boundary spatial coordinate.*

- Real top_bndy_

  *Top boundary spatial coordinate.*

- int num_cells_z_

  *Number of cells discretizing the domain.*

- Real delta_z_

  *Computed $\Delta z$.*

## Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid3D &in)

  *Prints the grid as a tuple of arrays.*

### 16.24.1 Detailed Description

Uniform 3D Staggered Grid.

Definition at line 79 of file mtk_uni_stg_grid_3d.h.

### 16.24.2 Constructor & Destructor Documentation

#### 16.24.2.1 mtk::UniStgGrid3D::UniStgGrid3D ( )

Definition at line 116 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.2.2 mtk::UniStgGrid3D::UniStgGrid3D ( const UniStgGrid3D & *grid* )

**Parameters**

| | | |
|---|---|---|
| in | *grid* | Given grid. |

Definition at line 135 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.2.3 mtk::UniStgGrid3D::UniStgGrid3D ( const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const Real & *south_bndy_y*, const Real & *north_bndy_y*, const int & *num_cells_y*, const Real & *bottom_bndy_z*, const Real & *top_bndy_z*, const int & *num_cells_z*, const mtk::FieldNature & *nature* = mtk::SCALAR )

**Parameters**

| | | |
|---|---|---|
| in | *west_bndy_x* | Coordinate for the west boundary. |
| in | *east_bndy_x* | Coordinate for the east boundary. |

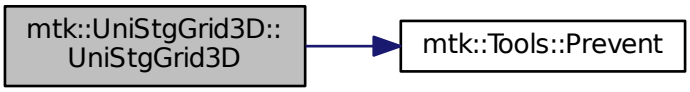
| | | |
|---|---|---|
| in | *num_cells_x* | Number of cells of the required grid. |
| in | *south_bndy_y* | Coordinate for the west boundary. |
| in | *north_bndy_y* | Coordinate for the east boundary. |
| in | *num_cells_y* | Number of cells of the required grid. |
| in | *bottom_bndy_z* | Coordinate for the bottom boundary. |
| in | *top_bndy_z* | Coordinate for the top boundary. |
| in | *num_cells_z* | Number of cells of the required grid. |
| in | *nature* | Nature of the discrete field to hold. |

**See also**

mtk::FieldNature

Definition at line 167 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:




#### 16.24.2.4 mtk::UniStgGrid3D::∼UniStgGrid3D ( )

Definition at line 214 of file mtk_uni_stg_grid_3d.cc.

### 16.24.3 Member Function Documentation

#### 16.24.3.1 void mtk::UniStgGrid3D::BindScalarField ( Real(∗)(const Real &xx, const Real &yy, const Real &zz) *ScalarField* )

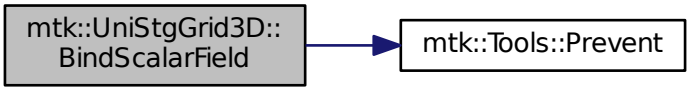
**Parameters**

| | | |
|---|---|---|
| in | *ScalarField* | Pointer to the function implementing the scalar field. |

1. Create collection of spatial coordinates for $x$.
2. Create collection of spatial coordinates for $y$.
3. Create collection of spatial coordinates for $z$.
4. Create collection of field samples.

Definition at line 311 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:




#### 16.24.3.2 void mtk::UniStgGrid3D::BindVectorField ( Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldPComponent*, Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldQComponent*, Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldRComponent* )

We assume the field to be of the form:

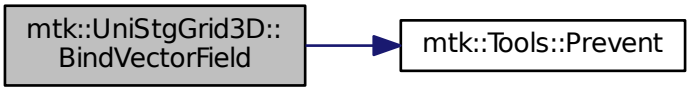
$$\mathbf{v}(\mathbf{x}) = p(x,y,z)\hat{\mathbf{i}} + q(x,y,z)\hat{\mathbf{j}} + r(x,y,z)\hat{\mathbf{k}}$$

**Parameters**

| | | |
|---|---|---|
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ p $ component of the vector field. |
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ q $ component of the vector field. |
| in | *VectorFieldR↩ Component* | Pointer to the function implementing the $ r $ component of the vector field. |

Definition at line 394 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:




#### 16.24.3.3 void mtk::UniStgGrid3D::BindVectorFieldPComponent ( Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldPComponent* ) [private]

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = p(x,y,z)\hat{\mathbf{i}} + q(x,y,z)\hat{\mathbf{j}} + r(x,y,z)\hat{\mathbf{k}}$$

**Parameters**

| | | |
|---|---|---|
| in | *BindVectorField↩ PComponent* | Pointer to the function implementing the $ p $ component of the vector field. |

Definition at line 373 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.4 void mtk::UniStgGrid3D::BindVectorFieldQComponent ( Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldQComponent* ) [private]

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = p(x,y,z)\hat{\mathbf{i}} + q(x,y,z)\hat{\mathbf{j}} + r(x,y,z)\hat{\mathbf{k}}$$

**Parameters**

| | | |
|---|---|---|
| in | *BindVectorField↩ QComponent* | Pointer to the function implementing the $ q $ component of the vector field. |

Definition at line 380 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.5 void mtk::UniStgGrid3D::BindVectorFieldRComponent ( Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldRComponent* ) [private]

We assume the field to be of the form:

$$\mathbf{v}(\mathbf{x}) = p(x,y,z)\hat{\mathbf{i}} + q(x,y,z)\hat{\mathbf{j}} + r(x,y,z)\hat{\mathbf{k}}$$

**Parameters**

| | | |
|---|---|---|
| in | *BindVectorField↩ QComponent* | Pointer to the function implementing the $ r $ component of the vector field. |

Definition at line 387 of file mtk_uni_stg_grid_3d.cc.

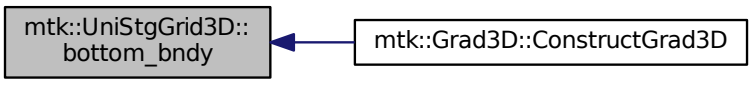
#### 16.24.3.6 mtk::Real mtk::UniStgGrid3D::bottom_bndy ( ) const

**Returns**

Bottom boundary spatial coordinate.

Definition at line 271 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



#### 16.24.3.7 bool mtk::UniStgGrid3D::Bound ( ) const

**Returns**

True is a field has been bound.

Definition at line 301 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.8 mtk::Real mtk::UniStgGrid3D::delta_x ( ) const

**Returns**

Computed $ x $.

Definition at line 236 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.9 mtk::Real mtk::UniStgGrid3D::delta_y ( ) const

**Returns**

Computed $ y $.

Definition at line 261 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.10 mtk::Real mtk::UniStgGrid3D::delta_z ( ) const

**Returns**

Computed $ z $.

Definition at line 286 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.11 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_x ( ) const

**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 241 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.12 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_y ( ) const

**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 266 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.13 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_z ( ) const

**Returns**

Pointer to the spatial data.

**Todo** Review const-correctness of the pointer we return.

Definition at line 291 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.14 mtk::Real * mtk::UniStgGrid3D::discrete_field ( )

**Returns**

Pointer to the field data.

Definition at line 296 of file mtk_uni_stg_grid_3d.cc.

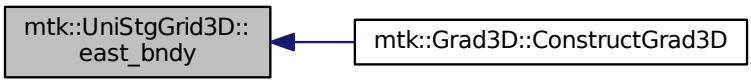
#### 16.24.3.15 mtk::Real mtk::UniStgGrid3D::east_bndy ( ) const

**Returns**

East boundary spatial coordinate.

Definition at line 226 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:




#### 16.24.3.16 mtk::FieldNature mtk::UniStgGrid3D::nature ( ) const

**Returns**

Value of an enumeration.

**See also**

mtk::FieldNature

Definition at line 216 of file mtk_uni_stg_grid_3d.cc.

#### 16.24.3.17 mtk::Real mtk::UniStgGrid3D::north_bndy ( ) const

**Returns**

North boundary spatial coordinate.

Definition at line 251 of file mtk_uni_stg_grid_3d.cc.

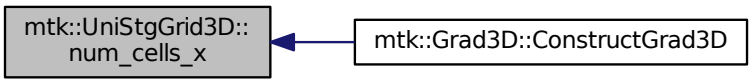
#### 16.24.3.18 int mtk::UniStgGrid3D::num_cells_x ( ) const

**Returns**

Number of cells of the grid.

Definition at line 231 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



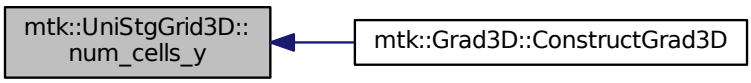

#### 16.24.3.19 int mtk::UniStgGrid3D::num_cells_y ( ) const

**Returns**

Number of cells of the grid.

Definition at line 256 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



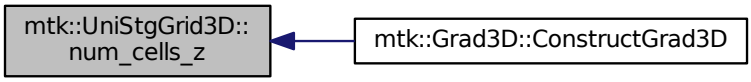

#### 16.24.3.20 int mtk::UniStgGrid3D::num_cells_z ( ) const

**Returns**

Number of cells of the grid.

Definition at line 281 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:




#### 16.24.3.21 int mtk::UniStgGrid3D::Size ( ) const

**Returns**

Total number of samples in the grid.

Definition at line 306 of file mtk_uni_stg_grid_3d.cc.

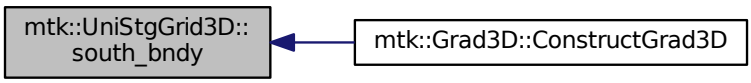
#### 16.24.3.22 mtk::Real mtk::UniStgGrid3D::south_bndy ( ) const

**Returns**

South boundary spatial coordinate.

Definition at line 246 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



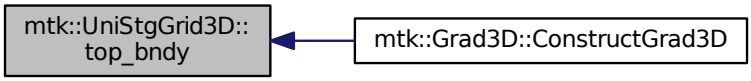

#### 16.24.3.23 mtk::Real mtk::UniStgGrid3D::top_bndy ( ) const

**Returns**

Top boundary spatial coordinate.

Definition at line 276 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



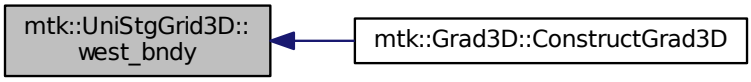

#### 16.24.3.24 mtk::Real mtk::UniStgGrid3D::west_bndy ( ) const

**Returns**

West boundary spatial coordinate.

Definition at line 221 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:




#### 16.24.3.25 bool mtk::UniStgGrid3D::WriteToFile ( std::string *filename*, std::string *space_name_x*, std::string *space_name_y*, std::string *space_name_z*, std::string *field_name* ) const

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |
| in | *space_name_x* | Name for the first column of the (spatial) data. |
| in | *space_name_y* | Name for the second column of the (spatial) data. |
| in | *space_name_z* | Name for the third column of the (spatial) data. |

| | | |
|---|---|---|
| in | *field_name* | Name for the second column of the (physical field) data. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Definition at line 413 of file mtk_uni_stg_grid_3d.cc.

### 16.24.4 Friends And Related Function Documentation

#### 16.24.4.1 std::ostream& operator<< ( std::ostream & *stream,* mtk::UniStgGrid3D & *in* ) [friend]

1. Print spatial coordinates.
2. Print scalar field.

Definition at line 67 of file mtk_uni_stg_grid_3d.cc.

### 16.24.5 Member Data Documentation

#### 16.24.5.1 Real mtk::UniStgGrid3D::bottom_bndy_ [private]

Definition at line 387 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.2 Real mtk::UniStgGrid3D::delta_x_ [private]

Definition at line 380 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.3 Real mtk::UniStgGrid3D::delta_y_ [private]

Definition at line 385 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.4 Real mtk::UniStgGrid3D::delta_z_ [private]

Definition at line 390 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.5 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_x_ [private]

Definition at line 370 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.6 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_y_ [private]

Definition at line 371 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.7 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_z_ [private]

Definition at line 372 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.8 std::vector<Real> mtk::UniStgGrid3D::discrete_field_ [private]

Definition at line 373 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.9 Real mtk::UniStgGrid3D::east_bndy_ [private]

Definition at line 378 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.10 FieldNature mtk::UniStgGrid3D::nature_ [private]

Definition at line 375 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.11 Real mtk::UniStgGrid3D::north_bndy_ [private]

Definition at line 383 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.12 int mtk::UniStgGrid3D::num_cells_x_ [private]

Definition at line 379 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.13 int mtk::UniStgGrid3D::num_cells_y_ [private]

Definition at line 384 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.14 int mtk::UniStgGrid3D::num_cells_z_ [private]

Definition at line 389 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.15 Real mtk::UniStgGrid3D::south_bndy_ [private]

Definition at line 382 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.16 Real mtk::UniStgGrid3D::top_bndy_ [private]

Definition at line 388 of file mtk_uni_stg_grid_3d.h.

#### 16.24.5.17 Real mtk::UniStgGrid3D::west_bndy_ [private]

Definition at line 377 of file mtk_uni_stg_grid_3d.h.

The documentation for this class was generated from the following files:

- include/mtk_uni_stg_grid_3d.h

- src/mtk_uni_stg_grid_3d.cc

# Chapter 17

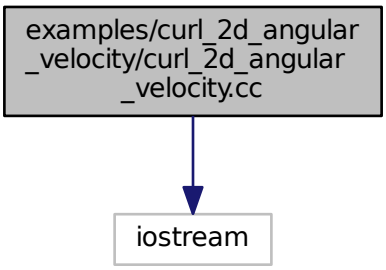
# File Documentation

## 17.1 examples/curl_2d_angular_velocity/curl_2d_angular_velocity.cc File Reference

Compute the curl of a 2D angular velocity field.

```
#include <iostream>
```

Include dependency graph for curl_2d_angular_velocity.cc:




### Functions

- int main ()

### 17.1.1 Detailed Description

We compute the curl of:

$$\mathbf{v}(x,y) = -y\hat{\mathbf{i}} + x\hat{\mathbf{j}}.$$

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file curl_2d_angular_velocity.cc.

### 17.1.2 Function Documentation

#### 17.1.2.1 int main ( )

Definition at line 106 of file curl_2d_angular_velocity.cc.

## 17.2 curl_2d_angular_velocity.cc

```
00001
00013 /*
00014 Copyright (C) 2015, Computational Science Research Center, San Diego State
00015 University. All rights reserved.
00016
00017 Redistribution and use in source and binary forms, with or without modification,
00018 are permitted provided that the following conditions are met:
00019
00020 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00021 and a copy of the modified files should be reported once modifications are
00022 completed, unless these modifications are made through the project's GitHub
00023 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00024 should be developed and included in any deliverable.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions in binary form must reproduce the above copyright notice,
00030 this list of conditions and the following disclaimer in the documentation and/or
00031 other materials provided with the distribution.
00032
00033 4. Usage of the binary form on proprietary applications shall require explicit
00034 prior written permission from the the copyright holders, and due credit should
00035 be given to the copyright holders.
00036
00037 5. Neither the name of the copyright holder nor the names of its contributors
00038 may be used to endorse or promote products derived from this software without
00039 specific prior written permission.
00040
00041 The copyright holders provide no reassurances that the source code provided does
00042 not infringe any patent, copyright, or any other intellectual property rights of
00043 third parties. The copyright holders disclaim any liability to any recipient for
00044 claims brought against recipient by any third party for infringement of that
00045 parties intellectual property rights.
00046
00047 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00048 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00049 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00050 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00051 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00052 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00053 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #if __cplusplus == 201103L
00060
00061 #include <iostream>
00062 #include <fstream>
00063 #include <cmath>
00064
00065 #include <vector>
00066
00067 #include "mtk.h"
00068
```

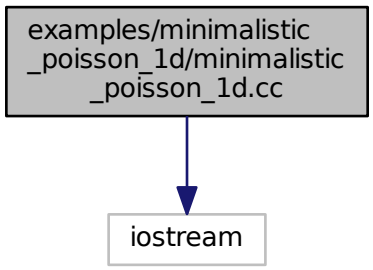
```
00069 mtk::Real VectorFieldPComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00070
00071   return -yy;
00072 }
00073
00074 mtk::Real VectorFieldQComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00075
00076   return xx;
00077 }
00078
00079 int main () {
00080
00081   std::cout << "Example: Curl of a angular velocity field." << std::endl;
00082
00084   mtk::Real aa = 0.0;
00085   mtk::Real bb = 4.0;
00086   mtk::Real cc = 0.0;
00087   mtk::Real dd = 4.0;
00088
00089   int nn = 10;
00090   int mm = 10;
00091
00092   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00093
00094   gg.BindVectorField(VectorFieldPComponent, VectorFieldQComponent);
00095
00096   if(!gg.WriteToFile("curl_2d_angular_velocity_gg.dat", "x", "y", "v(x,y)")) {
00097     std::cerr << "Angular field could not be written to disk." << std::endl;
00098     return EXIT_FAILURE;
00099   }
00100 }
00101
00102 #else
00103 #include <iostream>
00104 using std::cout;
00105 using std::endl;
00106 int main () {
00107   cout << "This code HAS to be compiled with support for C++11." << endl;
00108   cout << "Exiting..." << endl;
00109   return EXIT_SUCCESS;
00110 }
00111 #endif
```

## 17.3 examples/minimalistic_poisson_1d/minimalistic_poisson_1d.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`

Include dependency graph for minimalistic_poisson_1d.cc:



### Functions

- int main ()

#### 17.3.1 Detailed Description

We solve:

$$-\nabla^2 p(x) = s(x),$$

for $x \in \Omega = [a,b] = [0,1]$.

The source term function is defined as:

$$s(x) = -\frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1},$$

where $\lambda = -1$ is a real-valued parameter.

We consider Robin's boundary conditions of the form:

$$\alpha p(a) - \beta p'(a) = \omega,$$

$$\alpha p(b) + \beta p'(b) = \varepsilon,$$

where $\alpha = -\exp(\lambda)$, $\beta = (\exp(\lambda) - 1.0)/\lambda$, $\omega = -1$, and $\varepsilon = 0$.

The analytical solution for this problem is given by:

$$p(x) = \frac{\exp(\lambda x) - 1}{\exp(\lambda) - 1}.$$

The mimetic counterpart of this equation is:

$$-\check{\mathbf{L}}_x^k \tilde{p} = \tilde{s}.$$

Finally, we will solve this problem considering $k = 2$.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file minimalistic_poisson_1d.cc.

#### 17.3.2 Function Documentation

##### 17.3.2.1 int main ( )

Definition at line 164 of file minimalistic_poisson_1d.cc.

## 17.4 minimalistic_poisson_1d.cc

```
00001
00043 /*
00044 Copyright (C) 2015, Computational Science Research Center, San Diego State
00045 University. All rights reserved.
00046
00047 Redistribution and use in source and binary forms, with or without modification,
00048 are permitted provided that the following conditions are met:
00049
00050 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
```

```
00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00058
00059 3. Redistributions in binary form must reproduce the above copyright notice,
00060 this list of conditions and the following disclaimer in the documentation and/or
00061 other materials provided with the distribution.
00062
00063 4. Usage of the binary form on proprietary applications shall require explicit
00064 prior written permission from the the copyright holders, and due credit should
00065 be given to the copyright holders.
00066
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00068 may be used to endorse or promote products derived from this software without
00069 specific prior written permission.
00070
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00072 not infringe any patent, copyright, or any other intellectual property rights of
00073 third parties. The copyright holders disclaim any liability to any recipient for
00074 claims brought against recipient by any third party for infringement of that
00075 parties intellectual property rights.
00076
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00078 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00079 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00080 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00081 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00082 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00083 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #if __cplusplus == 201103L
00090
00091 #include <iostream>
00092 #include <fstream>
00093 #include <cmath>
00094 #include <vector>
00095
00096 #include "mtk.h"
00097
00098 mtk::Real Alpha(const mtk::Real &tt) {
00099   mtk::Real lambda = -1.0;
00100   return -exp(lambda);
00101 }
00102
00103 mtk::Real Beta(const mtk::Real &tt) {
00104   mtk::Real lambda = -1.0;
00105   return (exp(lambda) - 1.0)/lambda;
00106 };
00107
00108 mtk::Real Omega(const mtk::Real &tt) { return -1.0; };
00109
00110 mtk::Real Epsilon(const mtk::Real &tt) { return 0.0; };
00111
00112 mtk::Real Source(const mtk::Real &xx) {
00113   mtk::Real lambda = -1.0;
00114   return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00115 }
00116
00117 mtk::Real KnownSolution(const mtk::Real &xx) {
00118   mtk::Real lambda = -1.0;
00119   return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00120 }
00121
00122 int main () {
00123
00124   mtk::Real west_bndy_x{};
00125   mtk::Real east_bndy_x{1.0};
00126   int num_cells_x{5};
00127   mtk::Lap1D lap;
00128   if (!lap.ConstructLap1D()) {
00129     return EXIT_FAILURE;
00130   }
00131   mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
```
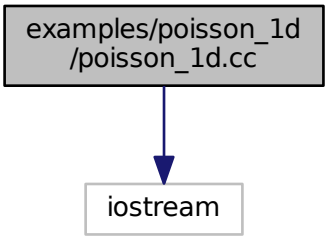

```
00132   mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00133   mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00134   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00135   source.BindScalarField(Source);
00136   mtk::RobinBCDescriptor1D bcs;
00137   bcs.PushBackWestCoeff(Alpha);
00138   bcs.PushBackWestCoeff(Beta);
00139   bcs.PushBackEastCoeff(Alpha);
00140   bcs.PushBackEastCoeff(Beta);
00141   bcs.set_west_condition(Omega);
00142   bcs.set_east_condition(Epsilon);
00143   if (!bcs.ImposeOnLaplacianMatrix(lap, lapm)) {
00144     return EXIT_FAILURE;
00145   }
00146   bcs.ImposeOnGrid(source);
00147   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00148   if (info != 0) {
00149     return EXIT_FAILURE;
00150   }
00151   source.WriteToFile("minimalistic_poisson_1d_comp_sol.dat", "x", "~u(x)");
00152   known_sol.BindScalarField(KnownSolution);
00153   known_sol.WriteToFile("minimalistic_poisson_1d_known_sol.dat", "x", "u(x)");
00154   mtk::Real relative_norm_2_error =
00155     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00156                                     known_sol.discrete_field(),
00157                                     known_sol.num_cells_x());
00158   std::cout << relative_norm_2_error << std::endl;
00159 }
00160 #else
00161 #include <iostream>
00162 using std::cout;
00163 using std::endl;
00164 int main () {
00165   cout << "This code HAS to be compiled with support for C++11." << endl;
00166   cout << "Exiting..." << endl;
00167   return EXIT_SUCCESS;
00168 }
00169 #endif
```

## 17.5 examples/poisson_1d/poisson_1d.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`
Include dependency graph for poisson_1d.cc:




### Functions

- int main ()

### 17.5.1 Detailed Description

We solve:

$$-\nabla^2 p(x) = s(x),$$

for $x \in \Omega = [a,b] = [0,1]$.

The source term function is defined as:

$$s(x) = -\frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1},$$

where $\lambda = -1$ is a real-valued parameter.

We consider Robin's boundary conditions of the form:

$$\alpha p(a) - \beta p'(a) = \omega,$$

$$\alpha p(b) + \beta p'(b) = \varepsilon,$$

where $\alpha = -\exp(\lambda)$, $\beta = (\exp(\lambda) - 1.0)/\lambda$, $\omega = -1$, and $\varepsilon = 0$.

The analytical solution for this problem is given by:

$$p(x) = \frac{\exp(\lambda x) - 1}{\exp(\lambda) - 1}.$$

The mimetic counterpart of this equation is:

$$-\check{\mathbf{L}}_x^k \tilde{p} = \tilde{s}.$$

Finally, we will solve this problem considering $k = 2$.

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file poisson_1d.cc.

### 17.5.2 Function Documentation

#### 17.5.2.1 int main ( )

Definition at line 263 of file poisson_1d.cc.

## 17.6 poisson_1d.cc

```
00001
00043 /*
00044 Copyright (C) 2015, Computational Science Research Center, San Diego State
00045 University. All rights reserved.
00046
00047 Redistribution and use in source and binary forms, with or without modification,
00048 are permitted provided that the following conditions are met:
00049
00050 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
```

```
00058
00059 3. Redistributions in binary form must reproduce the above copyright notice,
00060 this list of conditions and the following disclaimer in the documentation and/or
00061 other materials provided with the distribution.
00062
00063 4. Usage of the binary form on proprietary applications shall require explicit
00064 prior written permission from the the copyright holders, and due credit should
00065 be given to the copyright holders.
00066
00067 5. Neither the name of the copyright holder nor the names of its contributors
00068 may be used to endorse or promote products derived from this software without
00069 specific prior written permission.
00070
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00076
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00078 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00079 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00080 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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00082 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00083 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #if __cplusplus == 201103L
00090
00091 #include <iostream>
00092 #include <fstream>
00093 #include <cmath>
00094
00095 #include <vector>
00096
00097 #include "mtk.h"
00098
00099 mtk::Real Alpha(const mtk::Real &tt) {
00100
00101   mtk::Real lambda{-1.0};
00102
00103   return -exp(lambda);
00104 }
00105
00106 mtk::Real Beta(const mtk::Real &tt) {
00107
00108   mtk::Real lambda{-1.0};
00109
00110   return (exp(lambda) - 1.0)/lambda;
00111 };
00112
00113 mtk::Real Omega(const mtk::Real &tt) {
00114
00115   return -1.0;
00116 };
00117
00118 mtk::Real Epsilon(const mtk::Real &tt) {
00119
00120   return 0.0;
00121 };
00122
00123 mtk::Real Source(const mtk::Real &xx) {
00124
00125   mtk::Real lambda{-1.0};
00126
00127   return -lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00128 }
00129
00130 mtk::Real KnownSolution(const mtk::Real &xx) {
00131
00132   mtk::Real lambda{-1.0};
00133
00134   return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00135 }
00136
00137 int main () {
00138
```

```
00139   std::cout << "Example: Poisson Equation with Robin BCs on a";
00140   std::cout << "1D Uniform Staggered Grid." << std::endl;
00141
00143   mtk::Real west_bndy_x{0.0};
00144   mtk::Real east_bndy_x{1.0};
00145   int num_cells_x{5};
00146
00147   mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00148
00150   mtk::Lap1D lap;
00151
00152   if (!lap.ConstructLap1D()) {
00153     std::cerr << "Mimetic Laplacian could not be built." << std::endl;
00154     return EXIT_FAILURE;
00155   }
00156
00157   std::cout << "lap=" << std::endl;
00158   std::cout << lap << std::endl;
00159
00160   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00161
00162   std::cout << "lapm =" << std::endl;
00163   std::cout << lapm << std::endl;
00164
00166
00167   lapm = mtk::BLASAdapter::RealDenseSM(-1.0, lapm);
00168
00169   std::cout << "-lapm =" << std::endl;
00170   std::cout << lapm << std::endl;
00171
00173   mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00174
00175   source.BindScalarField(Source);
00176
00177   std::cout << "source =" << std::endl;
00178   std::cout << source << std::endl;
00179
00181   mtk::RobinBCDescriptor1D robin_bc_desc_1d;
00182
00183   robin_bc_desc_1d.PushBackWestCoeff(Alpha);
00184   robin_bc_desc_1d.PushBackWestCoeff(Beta);
00185
00186   robin_bc_desc_1d.PushBackEastCoeff(Alpha);
00187   robin_bc_desc_1d.PushBackEastCoeff(Beta);
00188
00189   robin_bc_desc_1d.set_west_condition(Omega);
00190   robin_bc_desc_1d.set_east_condition(Epsilon);
00191
00192   if (!robin_bc_desc_1d.ImposeOnLaplacianMatrix(lap, lapm)) {
00193     std::cerr << "BCs  could not be bound to the matrix." << std::endl;
00194     return EXIT_FAILURE;
00195   }
00196
00197   std::cout << "Mimetic Laplacian operator with imposed BCs:" << std::endl;
00198   std::cout << lapm << std::endl;
00199
00200   if (!lapm.WriteToFile("poisson_1d_lapm.dat")) {
00201     std::cerr << "Laplacian matrix could not be written to disk." << std::endl;
00202     return EXIT_FAILURE;
00203   }
00204
00206   robin_bc_desc_1d.ImposeOnGrid(source);
00207
00208   std::cout << "source =" << std::endl;
00209   std::cout << source << std::endl;
00210
00211   if (!source.WriteToFile("poisson_1d_source.dat", "x", "s(x)")) {
00212     std::cerr << "Source term could not be written to disk." << std::endl;
00213     return EXIT_FAILURE;
00214   }
00215
00217   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00218
00219   if (!info) {
00220     std::cout << "System solved." << std::endl;
00221     std::cout << std::endl;
00222   } else {
00223     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00224     std::cerr << "Exiting..." << std::endl;
00225     return EXIT_FAILURE;
00226   }
```

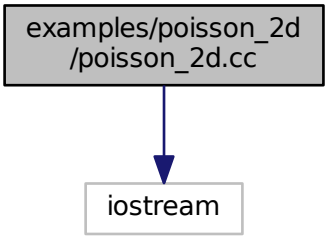
```
00227
00228   std::cout << "Computed solution:" << std::endl;
00229   std::cout << source << std::endl;
00230
00231   if (!source.WriteToFile("poisson_1d_comp_sol.dat", "x", "~u(x)")) {
00232     std::cerr << "Solution could not be written to file." << std::endl;
00233     return EXIT_FAILURE;
00234   }
00235
00237   mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00238
00239   known_sol.BindScalarField(KnownSolution);
00240
00241   std::cout << "known_sol =" << std::endl;
00242   std::cout << known_sol << std::endl;
00243
00244   if (!known_sol.WriteToFile("poisson_1d_known_sol.dat", "x", "u(x)")) {
00245     std::cerr << "Known solution could not be written to file." << std::endl;
00246     return EXIT_FAILURE;
00247   }
00248
00249   mtk::Real relative_norm_2_error{};
00250
00251   relative_norm_2_error =
00252     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00253                                     known_sol.discrete_field(),
00254                                     known_sol.num_cells_x());
00255
00256   std::cout << "relative_norm_2_error = ";
00257   std::cout << relative_norm_2_error << std::endl;
00258 }
00259 #else
00260 #include <iostream>
00261 using std::cout;
00262 using std::endl;
00263 int main () {
00264   cout << "This code HAS to be compiled with support for C++11." << endl;
00265   cout << "Exiting..." << endl;
00266   return EXIT_SUCCESS;
00267 }
00268 #endif
```

## 17.7 examples/poisson_2d/poisson_2d.cc File Reference

Poisson Equation on a 2D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`

Include dependency graph for poisson_2d.cc:



### Functions

- int main ()

### 17.7.1 Detailed Description

We solve:

$$\nabla^2 u(\mathbf{x}) = s(\mathbf{x}),$$

for $\mathbf{x} \in \Omega = [0,1]^2$.

The source term function is defined as

$$s(x,y) = xye^{-0.5(x^2+y^2)}(x^2+y^2-6).$$

Let $\partial\Omega = S \cup N \cup W \cup E$. We consider Dirichlet boundary conditions of the following form:

$$\forall \mathbf{x} \in W : u(\mathbf{x}) = 0.$$

$$\forall \mathbf{x} \in E : u(1,y) = -e^{-0.5(1-y^2)}(1-y^2).$$

$$\forall \mathbf{x} \in S : u(\mathbf{x}) = 0.$$

$$\forall \mathbf{x} \in N : u(x,1) = -e^{-0.5(x^2-1)}(x^2-1).$$

The analytical solution for this problem is given by

$$u(x,y) = xye^{-0.5(x^2+y^2)}.$$

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file poisson_2d.cc.

### 17.7.2 Function Documentation

#### 17.7.2.1 int main ( )

Definition at line 241 of file poisson_2d.cc.

## 17.8 poisson_2d.cc

```
00001
00039 /*
00040 Copyright (C) 2015, Computational Science Research Center, San Diego State
00041 University. All rights reserved.
00042
00043 Redistribution and use in source and binary forms, with or without modification,
00044 are permitted provided that the following conditions are met:
00045
00046 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00047 and a copy of the modified files should be reported once modifications are
00048 completed, unless these modifications are made through the project's GitHub
00049 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00050 should be developed and included in any deliverable.
00051
```

```
00052 2. Redistributions of source code must be done through direct
00053 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00054
00055 3. Redistributions in binary form must reproduce the above copyright notice,
00056 this list of conditions and the following disclaimer in the documentation and/or
00057 other materials provided with the distribution.
00058
00059 4. Usage of the binary form on proprietary applications shall require explicit
00060 prior written permission from the the copyright holders, and due credit should
00061 be given to the copyright holders.
00062
00063 5. Neither the name of the copyright holder nor the names of its contributors
00064 may be used to endorse or promote products derived from this software without
00065 specific prior written permission.
00066
00067 The copyright holders provide no reassurances that the source code provided does
00068 not infringe any patent, copyright, or any other intellectual property rights of
00069 third parties. The copyright holders disclaim any liability to any recipient for
00070 claims brought against recipient by any third party for infringement of that
00071 parties intellectual property rights.
00072
00073 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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00075 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00077 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00078 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00079 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00080 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00081 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00082 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00083 */
00084
00085 #if __cplusplus == 201103L
00086
00087 #include <iostream>
00088 #include <fstream>
00089 #include <cmath>
00090
00091 #include <vector>
00092
00093 #include "mtk.h"
00094
00095 mtk::Real Source(const mtk::Real &xx, const mtk::Real &yy) {
00096
00097   mtk::Real x_squared{xx*xx};
00098   mtk::Real y_squared{yy*yy};
00099   mtk::Real aux{-0.5*(x_squared + y_squared)};
00100
00101   return xx*yy*exp(aux)*(x_squared + y_squared - 6.0);
00102 }
00103
00104 mtk::Real BCCoeff(const mtk::Real &xx, const mtk::Real &yy) {
00105
00106   return mtk::kOne;
00107 }
00108
00109 mtk::Real WestBC(const mtk::Real &xx, const mtk::Real &tt) {
00110
00111   return mtk::kZero;
00112 }
00113
00114 mtk::Real EastBC(const mtk::Real &yy, const mtk::Real &tt) {
00115
00116   return yy*exp(-0.5*(mtk::kOne + yy*yy));
00117 }
00118
00119 mtk::Real SouthBC(const mtk::Real &xx, const mtk::Real &tt) {
00120
00121   return mtk::kZero;
00122 }
00123
00124 mtk::Real NorthBC(const mtk::Real &xx, const mtk::Real &tt) {
00125
00126   return xx*exp(-0.5*(xx*xx + mtk::kOne));
00127 }
00128
00129 mtk::Real KnownSolution(const mtk::Real &xx, const mtk::Real &yy) {
00130
00131   mtk::Real x_squared{xx*xx};
00132   mtk::Real y_squared{yy*yy};
```

```
00133   mtk::Real aux{-0.5*(x_squared + y_squared)};
00134
00135   return xx*yy*exp(aux);
00136 }
00137
00138 int main () {
00139
00140   std::cout << "Example: Poisson Equation on a 2D Uniform Staggered Grid ";
00141   std::cout << "with Dirichlet and Neumann BCs." << std::endl;
00142
00144   mtk::Real west_bndy_x{0.0};
00145   mtk::Real east_bndy_x{1.0};
00146   mtk::Real south_bndy_y{0.0};
00147   mtk::Real north_bndy_y{1.0};
00148   int num_cells_x{5};
00149   int num_cells_y{5};
00150
00151   mtk::UniStgGrid2D comp_sol(west_bndy_x, east_bndy_x, num_cells_x,
00152                              south_bndy_y, north_bndy_y, num_cells_y);
00153
00155   mtk::Lap2D lap;
00156
00157   if (!lap.ConstructLap2D(comp_sol)) {
00158     std::cerr << "Mimetic Laplacian could not be built." << std::endl;
00159     return EXIT_FAILURE;
00160   }
00161
00162   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix());
00163
00165   mtk::UniStgGrid2D source(west_bndy_x, east_bndy_x, num_cells_x,
00166                            south_bndy_y, north_bndy_y, num_cells_y);
00167
00168   source.BindScalarField(Source);
00169
00171   mtk::RobinBCDescriptor2D bcd;
00172
00173   bcd.PushBackWestCoeff(BCCoeff);
00174   bcd.PushBackEastCoeff(BCCoeff);
00175   bcd.PushBackSouthCoeff(BCCoeff);
00176   bcd.PushBackNorthCoeff(BCCoeff);
00177
00178   bcd.ImposeOnLaplacianMatrix(lap, comp_sol, lapm);
00179
00180   if (!lapm.WriteToFile("poisson_2d_lapm.dat")) {
00181     std::cerr << "Laplacian matrix could not be written to disk." << std::endl;
00182     return EXIT_FAILURE;
00183   }
00184
00186   bcd.set_west_condition(WestBC);
00187   bcd.set_east_condition(EastBC);
00188   bcd.set_south_condition(SouthBC);
00189   bcd.set_north_condition(NorthBC);
00190
00191   bcd.ImposeOnGrid(source);
00192
00193   if(!source.WriteToFile("poisson_2d_source.dat", "x", "y", "s(x,y)")) {
00194     std::cerr << "Source term could not be written to disk." << std::endl;
00195     return EXIT_FAILURE;
00196   }
00197
00199   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00200
00201   if (!info) {
00202     std::cout << "System solved." << std::endl;
00203     std::cout << std::endl;
00204   } else {
00205     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00206     std::cerr << "Exiting..." << std::endl;
00207     return EXIT_FAILURE;
00208   }
00209
00210   if (!source.WriteToFile("poisson_2d_comp_sol.dat", "x", "y", "~u(x,y)")) {
00211     std::cerr << "Solution could not be written to file." << std::endl;
00212     return EXIT_FAILURE;
00213   }
00214
00216   mtk::UniStgGrid2D known_sol(west_bndy_x, east_bndy_x, num_cells_x,
00217                               south_bndy_y, north_bndy_y, num_cells_y);
00218
00219   known_sol.BindScalarField(KnownSolution);
00220
```

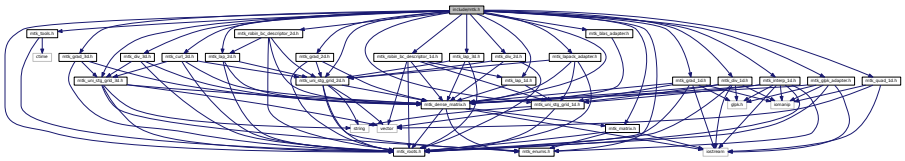
```
00221   if (!known_sol.WriteToFile("poisson_2d_known_sol.dat", "x", "y", "u(x,y)")) {
00222     std::cerr << "Known solution could not be written to file." << std::endl;
00223     return EXIT_FAILURE;
00224   }
00225
00226   mtk::Real relative_norm_2_error{};
00227
00228   relative_norm_2_error =
00229     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00230                                     known_sol.discrete_field(),
00231                                     known_sol.Size());
00232
00233   std::cout << "relative_norm_2_error = ";
00234   std::cout << relative_norm_2_error << std::endl;
00235 }
00236
00237 #else
00238 #include <iostream>
00239 using std::cout;
00240 using std::endl;
00241 int main () {
00242   cout << "This code HAS to be compiled with support for C++11." << endl;
00243   cout << "Exiting..." << endl;
00244   return EXIT_SUCCESS;
00245 }
00246 #endif
```

## 17.9 include/mtk.h File Reference

Includes the entire API.

```
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_tools.h"
#include "mtk_matrix.h"
#include "mtk_dense_matrix.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_uni_stg_grid_2d.h"
#include "mtk_uni_stg_grid_3d.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
#include "mtk_robin_bc_descriptor_1d.h"
#include "mtk_quad_1d.h"
#include "mtk_interp_1d.h"
#include "mtk_grad_2d.h"
#include "mtk_div_2d.h"
#include "mtk_curl_2d.h"
#include "mtk_lap_2d.h"
#include "mtk_robin_bc_descriptor_2d.h"
#include "mtk_grad_3d.h"
#include "mtk_div_3d.h"
#include "mtk_lap_3d.h"
```

Include dependency graph for mtk.h:



### 17.9.1 Detailed Description

This file contains every required header file, thus containing the entire API. In this way, client codes only have to instruct #include "mtk.h".

#### Warning

It is extremely important that the headers are added to this file in a specific order; that is, considering the dependence between the classes these contain.

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk.h.

## 17.10 mtk.h

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
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00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
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00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
```

```
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00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00358 #ifndef MTK_INCLUDE_MTK_H_
00359 #define MTK_INCLUDE_MTK_H_
00360
00368 #include "mtk_roots.h"
00369
00377 #include "mtk_enums.h"
00378
00386 #include "mtk_tools.h"
00387
00395 #include "mtk_matrix.h"
00396 #include "mtk_dense_matrix.h"
00397
00405 #include "mtk_blas_adapter.h"
00406 #include "mtk_lapack_adapter.h"
00407 #include "mtk_glpk_adapter.h"
00408
00416 #include "mtk_uni_stg_grid_1d.h"
00417 #include "mtk_uni_stg_grid_2d.h"
00418 #include "mtk_uni_stg_grid_3d.h"
00419
00427 #include "mtk_grad_1d.h"
00428 #include "mtk_div_1d.h"
00429 #include "mtk_lap_1d.h"
00430 #include "mtk_robin_bc_descriptor_1d.h"
00431 #include "mtk_quad_1d.h"
00432 #include "mtk_interp_1d.h"
00433
00434 #include "mtk_grad_2d.h"
00435 #include "mtk_div_2d.h"
00436 #include "mtk_curl_2d.h"
00437 #include "mtk_lap_2d.h"
00438 #include "mtk_robin_bc_descriptor_2d.h"
00439
00440 #include "mtk_grad_3d.h"
00441 #include "mtk_div_3d.h"
00442 #include "mtk_lap_3d.h"
00443
00444 #endif // End of: MTK_INCLUDE_MTK_H_
```
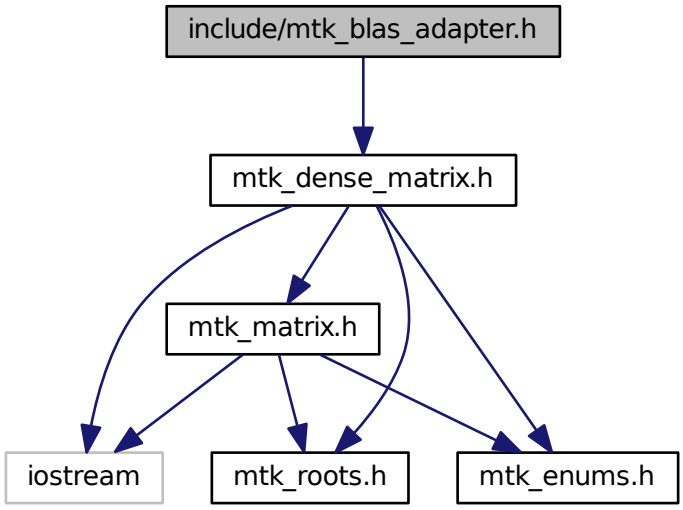

## 17.11 include/mtk_blas_adapter.h File Reference

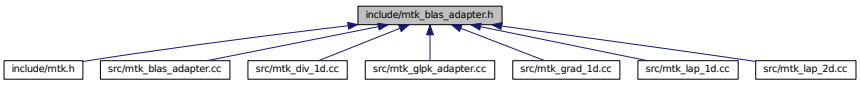
Adapter class for the BLAS API.

```
#include "mtk_dense_matrix.h"
```

Include dependency graph for mtk_blas_adapter.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::BLASAdapter

  *Adapter class for the BLAS API.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.11.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the BLAS.

The **BLAS (Basic Linear Algebra Subprograms)** are routines that provide standard building blocks for performing basic vector and matrix operations. The Level 1 BLAS perform scalar, vector and vector-vector operations, the Level 2 BLAS perform matrix-vector operations, and the Level 3 BLAS perform matrix-matrix operations.

The BLAS can be installed from links given in the See Also section of this page.

**See also**

http://www.netlib.org/blas/
https://software.intel.com/en-us/non-commercial-software-development

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_blas_adapter.h.

## 17.12 mtk_blas_adapter.h

```
00001
00024 /*
00025 Copyright (C) 2015, Computational Science Research Center, San Diego State
00026 University. All rights reserved.
00027
00028 Redistribution and use in source and binary forms, with or without modification,
00029 are permitted provided that the following conditions are met:
00030
00031 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00032 and a copy of the modified files should be reported once modifications are
00033 completed, unless these modifications are made through the project's GitHub
00034 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00035 should be developed and included in any deliverable.
00036
00037 2. Redistributions of source code must be done through direct
00038 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00039
00040 3. Redistributions in binary form must reproduce the above copyright notice,
00041 this list of conditions and the following disclaimer in the documentation and/or
00042 other materials provided with the distribution.
00043
00044 4. Usage of the binary form on proprietary applications shall require explicit
00045 prior written permission from the the copyright holders, and due credit should
00046 be given to the copyright holders.
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00048 5. Neither the name of the copyright holder nor the names of its contributors
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00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00071 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00072
00073 #include "mtk_dense_matrix.h"
```

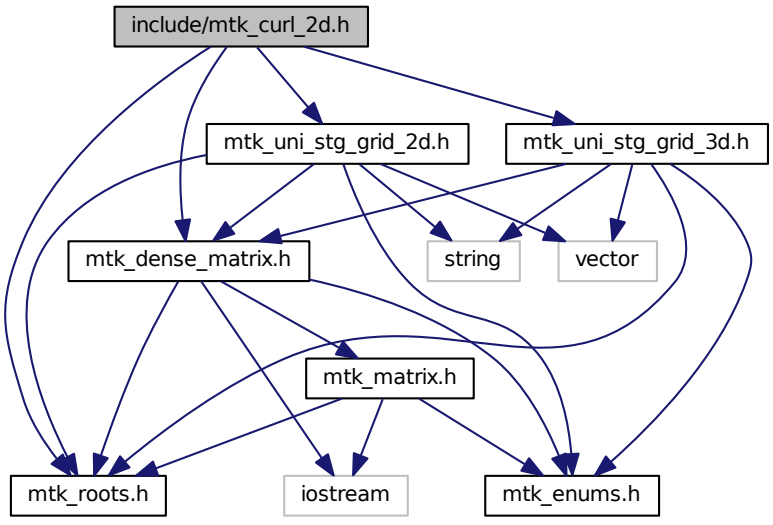
```
00074
00075 namespace mtk {
00076
00096 class BLASAdapter {
00097  public:
00106   static Real RealNRM2(Real *in, int &in_length);
00107
00124   static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00125
00140   static Real RelNorm2Error(Real *computed, Real *known, int length);
00141
00159   static void RealDenseMV(Real &alpha,
00160                           DenseMatrix &aa,
00161                           Real *xx,
00162                           Real &beta,
00163                           Real *yy);
00164
00179   static DenseMatrix RealDenseMM(DenseMatrix &aa,
      DenseMatrix &bb);
00180
00195   static DenseMatrix RealDenseSM(Real alpha,
      DenseMatrix &aa);
00196 };
00197 }
00198 #endif  // End of: MTK_INCLUDE_BLAS_ADAPTER_H_
```

## 17.13 include/mtk_curl_2d.h File Reference

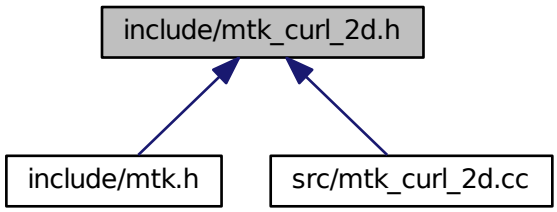
Includes the definition of the class Curl2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_curl_2d.h:



This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Curl2D

  *Implements a 2D mimetic curl operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

#### 17.13.1 Detailed Description

This class implements a 2D curl operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_curl_2d.h.

## 17.14 mtk_curl_2d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
```

```
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00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
00031 4. Usage of the binary form on proprietary applications shall require explicit
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_CURL_2D_H_
00058 #define MTK_INCLUDE_MTK_CURL_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063 #include "mtk_uni_stg_grid_3d.h"
00064
00065 namespace mtk{
00066
00077 class Curl2D {
00078  public:
00080   UniStgGrid3D operator*(const UniStgGrid2D &grid) const;
00081
00083   Curl2D();
00084
00090   Curl2D(const Curl2D &curl);
00091
00093   ~Curl2D();
00094
00100   bool ConstructCurl2D(const UniStgGrid2D &grid,
00101                        int order_accuracy = kDefaultOrderAccuracy,
00102                        Real mimetic_threshold = kDefaultMimeticThreshold);
00103
00109   DenseMatrix ReturnAsDenseMatrix() const;
00110
00111  private:
00112   DenseMatrix curl_;
00113
00114   int order_accuracy_;
00115
00116   Real mimetic_threshold_;
00117 };
00118 }
00119 #endif  // End of: MTK_INCLUDE_MTK_CURL_2D_H_
```
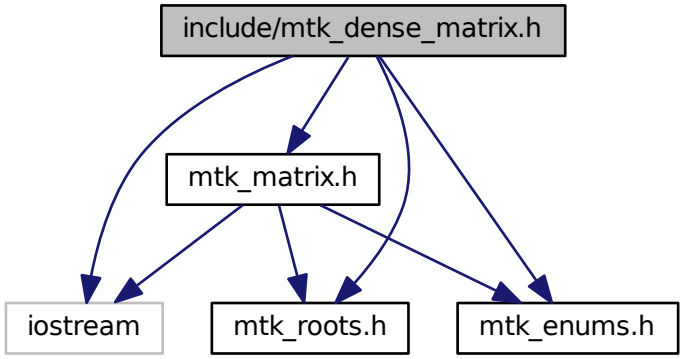

## 17.15 include/mtk_dense_matrix.h File Reference

Defines a common dense matrix, using a 1D array.

```
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_matrix.h"
```

Include dependency graph for mtk_dense_matrix.h:




This graph shows which files directly or indirectly include this file:

## Classes

- class mtk::DenseMatrix

  *Defines a common dense matrix, using a 1D array.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.15.1 Detailed Description

For developing purposes, it is better to have a not-so-intrincated data structure implementing matrices. This is the purpose of this class: to be used for prototypes of new code for small test cases. In every other instance, this should be replaced by the most appropriate sparse matrix.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Note**

We prefer composition to inheritance [Reedy, 2011]. The main reason for this preference is that inheritance produces a more tightly coupled design. When a class inherits from another type be it public, protected, or private inheritance the subclass gains access to all public and protected members of the base class, whereas with composition, the class is only coupled to the public members of the other class. Furthermore, if you only hold a pointer to the other object, then your interface can use a forward declaration of the class rather than #include its full definition. This results in greater compile-time insulation and improves the time it takes to compile your code.

Definition in file mtk_dense_matrix.h.

## 17.16 mtk_dense_matrix.h

```
00001
00023 /*
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00028 are permitted provided that the following conditions are met:
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00031 and a copy of the modified files should be reported once modifications are
00032 completed, unless these modifications are made through the project's GitHub
00033 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00034 should be developed and included in any deliverable.
00035
00036 2. Redistributions of source code must be done through direct
00037 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00064 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00065 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00066 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00067 */
00068
00069 #ifndef MTK_INCLUDE_DENSE_MATRIX_H_
00070 #define MTK_INCLUDE_DENSE_MATRIX_H_
00071
00072 #include <iostream>
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_enums.h"
00076 #include "mtk_matrix.h"
00077
00078 namespace mtk {
00079
00092 class DenseMatrix {
00093  public:
```

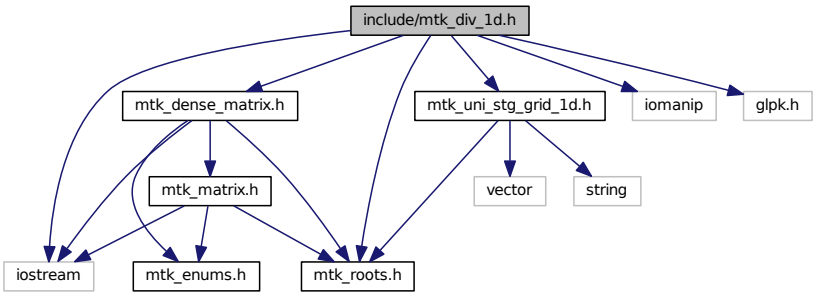
```
00095   friend std::ostream& operator <<(std::ostream &stream, DenseMatrix &in);
00096
00098   DenseMatrix& operator =(const DenseMatrix &in);
00099
00101   bool operator ==(const DenseMatrix &in);
00102
00104   DenseMatrix();
00105
00111   DenseMatrix(const DenseMatrix &in);
00112
00121   DenseMatrix(const int &num_rows, const int &num_cols);
00122
00148   DenseMatrix(const int &rank, const bool &padded, const bool &transpose);
00149
00183   DenseMatrix(const Real *const gen,
00184               const int &gen_length,
00185               const int &pro_length,
00186               const bool &transpose);
00187
00189   ~DenseMatrix();
00190
00196   Matrix matrix_properties() const noexcept;
00197
00203   int num_rows() const noexcept;
00204
00210   int num_cols() const noexcept;
00211
00217   Real* data() const noexcept;
00218
00226   void SetOrdering(mtk::MatrixOrdering oo) noexcept;
00227
00236   Real GetValue(const int &row_coord, const int &col_coord) const noexcept;
00237
00245   void SetValue(const int &row_coord,
00246                 const int &col_coord,
00247                 const Real &val) noexcept;
00248
00250   void Transpose();
00251
00253   void OrderRowMajor();
00254
00256   void OrderColMajor();
00257
00268   static DenseMatrix Kron(const DenseMatrix &aa,
00269                           const DenseMatrix &bb);
00270
00280   bool WriteToFile(const std::string &filename) const;
00281
00282  private:
00283   Matrix matrix_properties_;
00284
00285   Real *data_;
00286 };
00287 }
00288 #endif  // End of: MTK_INCLUDE_MTK_DENSE_MATRIX_H_
```

## 17.17 include/mtk_div_1d.h File Reference

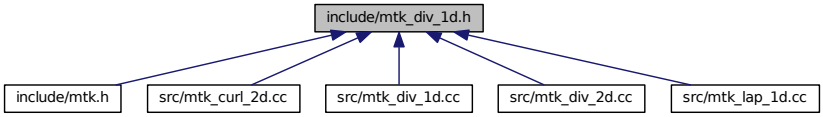
Includes the definition of the class Div1D.

```
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk_div_1d.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::Div1D

  *Implements a 1D mimetic divergence operator.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.17.1 Detailed Description

This class implements a 1D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_1d.h.

## 17.18 mtk_div_1d.h

```
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00011 /*
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00024 2. Redistributions of source code must be done through direct
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Div1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00085
00087   Div1D();
00088
00094   Div1D(const Div1D &div);
00095
00097   ~Div1D();
00098
00104   bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00105                       Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112   int num_bndy_coeffs() const;
00113
00119   Real *coeffs_interior() const;
00120
```

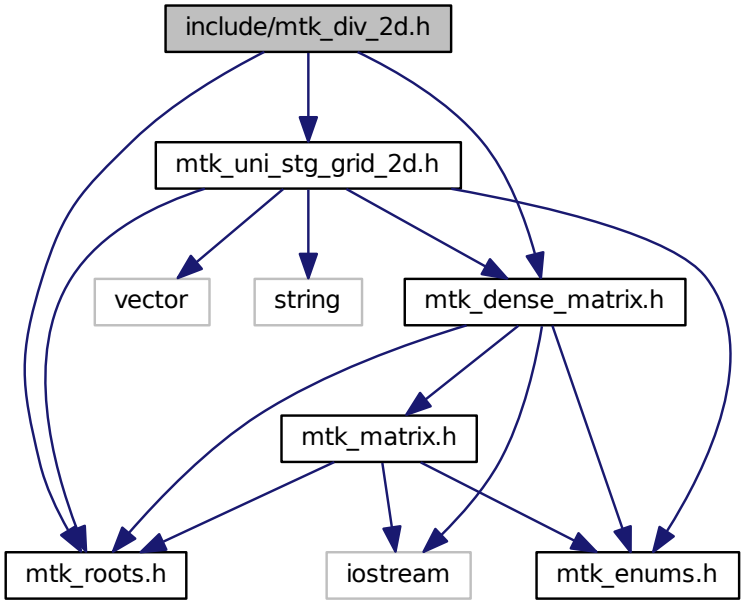
```
00126   Real *weights_crs(void) const;
00127
00133   Real *weights_cbs(void) const;
00134
00140   DenseMatrix mim_bndy() const;
00141
00147   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00148
00149  private:
00155   bool ComputeStencilInteriorGrid(void);
00156
00163   bool ComputeRationalBasisNullSpace(void);
00164
00170   bool ComputePreliminaryApproximations(void);
00171
00177   bool ComputeWeights(void);
00178
00184   bool ComputeStencilBoundaryGrid(void);
00185
00191   bool AssembleOperator(void);
00192
00193   int order_accuracy_;
00194   int dim_null_;
00195   int num_bndy_coeffs_;
00196   int divergence_length_;
00197   int minrow_;
00198   int row_;
00199
00200   DenseMatrix rat_basis_null_space_;
00201
00202   Real *coeffs_interior_;
00203   Real *prem_apps_;
00204   Real *weights_crs_;
00205   Real *weights_cbs_;
00206   Real *mim_bndy_;
00207   Real *divergence_;
00208
00209   Real mimetic_threshold_;
00210 };
00211 }
00212 #endif  // End of: MTK_INCLUDE_DIV_1D_H_
```

## 17.19 include/mtk_div_2d.h File Reference

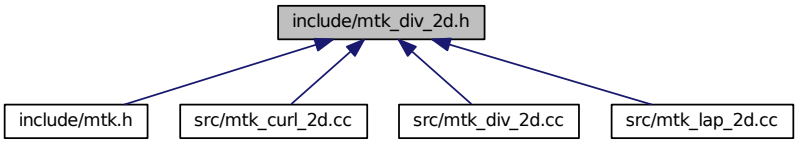
Includes the definition of the class Div2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_div_2d.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::Div2D

  *Implements a 2D mimetic divergence operator.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.19.1 Detailed Description

This class implements a 2D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_2d.h.

## 17.20 mtk_div_2d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_2D_H_
00058 #define MTK_INCLUDE_MTK_DIV_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Div2D {
00077  public:
00079   Div2D();
00080
```

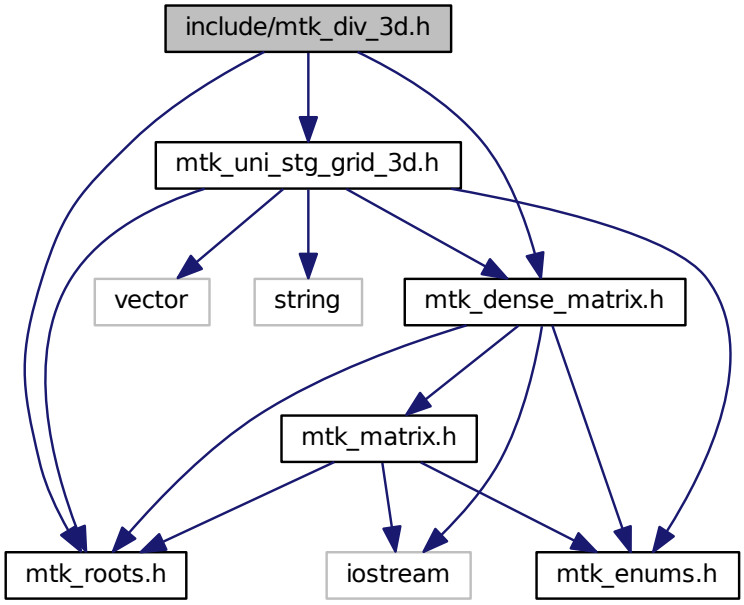
```
00086   Div2D(const Div2D &div);
00087
00089   ~Div2D();
00090
00096   bool ConstructDiv2D(const UniStgGrid2D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix divergence_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_DIV_2D_H_
```

## 17.21 include/mtk_div_3d.h File Reference

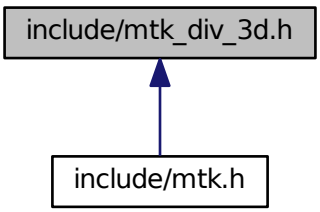
Includes the definition of the class Div3D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_div_3d.h:



This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Div3D

  *Implements a 3D mimetic divergence operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

#### 17.21.1 Detailed Description

This class implements a 3D divergence operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_3d.h.

## 17.22 mtk_div_3d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
```

```
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00027 3. Redistributions in binary form must reproduce the above copyright notice,
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_3D_H_
00058 #define MTK_INCLUDE_MTK_DIV_3D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_3d.h"
00063
00064 namespace mtk{
00065
00076 class Div3D {
00077  public:
00079   Div3D();
00080
00086   Div3D(const Div3D &div);
00087
00089   ~Div3D();
00090
00096   bool ConstructDiv3D(const UniStgGrid3D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix divergence_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_DIV_3D_H_
```
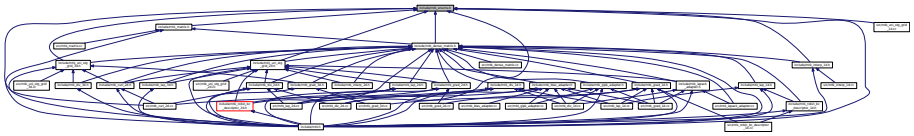

## 17.23 include/mtk_enums.h File Reference

Considered enumeration types in the MTK.

This graph shows which files directly or indirectly include this file:



### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Enumerations

- enum mtk::MatrixStorage { mtk::DENSE, mtk::BANDED, mtk::CRS }

  *Considered matrix storage schemes to implement sparse matrices.*
- enum mtk::MatrixOrdering { mtk::ROW_MAJOR, mtk::COL_MAJOR }

  *Considered matrix ordering (for Fortran purposes).*
- enum mtk::FieldNature { mtk::SCALAR, mtk::VECTOR }

  *Nature of the field discretized in a given grid.*
- enum mtk::DirInterp { mtk::SCALAR_TO_VECTOR, mtk::VECTOR_TO_SCALAR }

  *Interpolation operator.*

#### 17.23.1 Detailed Description

Enumeration types are used throughout the MTK to differentiate instances of derived classes, as well as for mnemonic purposes. In this file, the enumeration types are listed alphabetically.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_enums.h.

## 17.24 mtk_enums.h

```
00001
00012 /*
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00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
```

```
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00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_ENUMS_H_
00059 #define MTK_INCLUDE_ENUMS_H_
00060
00061 namespace mtk {
00062
00077 enum MatrixStorage {
00078   DENSE,
00079   BANDED,
00080   CRS
00081 };
00082
00095 enum MatrixOrdering {
00096   ROW_MAJOR,
00097   COL_MAJOR
00098 };
00099
00113 enum FieldNature {
00114   SCALAR,
00115   VECTOR
00116 };
00117
00127 enum DirInterp {
00128   SCALAR_TO_VECTOR,
00129   VECTOR_TO_SCALAR
00130 };
00131 }
00132 #endif  // End of: MTK_INCLUDE_ENUMS_H_
```
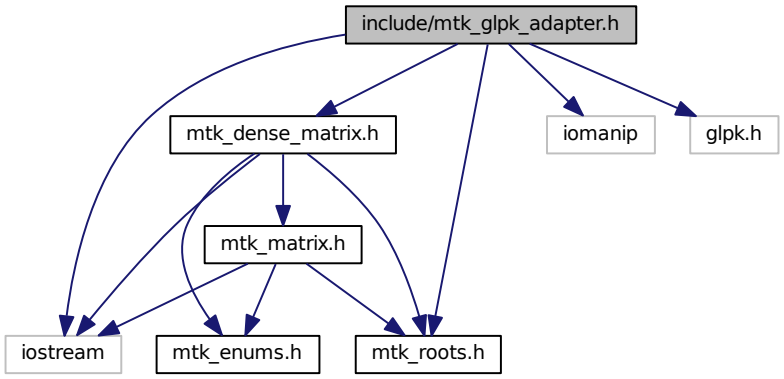

## 17.25 include/mtk_glpk_adapter.h File Reference

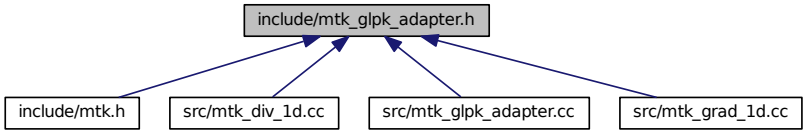
Adapter class for the GLPK API.

```
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
```

Include dependency graph for mtk_glpk_adapter.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::GLPKAdapter

  *Adapter class for the GLPK API.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.25.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the GLPK.

The **GLPK (GNU Linear Programming Kit)** package is intended for solving large-scale linear programming (LP), mixed integer programming (MIP), and other related problems. It is a set of routines written in ANSI C and organized in the form of a callable library.

**See also**

http://www.gnu.org/software/glpk/

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_glpk_adapter.h.

## 17.26 mtk_glpk_adapter.h

```
00001
00019 /*
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00021 University. All rights reserved.
00022
00023 Redistribution and use in source and binary forms, with or without modification,
00024 are permitted provided that the following conditions are met:
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00026 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00034
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00036 this list of conditions and the following disclaimer in the documentation and/or
00037 other materials provided with the distribution.
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00039 4. Usage of the binary form on proprietary applications shall require explicit
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00066 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00067
00068 #include <iostream>
00069 #include <iomanip>
00070
00071 #include "glpk.h"
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075
00076 namespace mtk {
00077
00101 class GLPKAdapter {
```

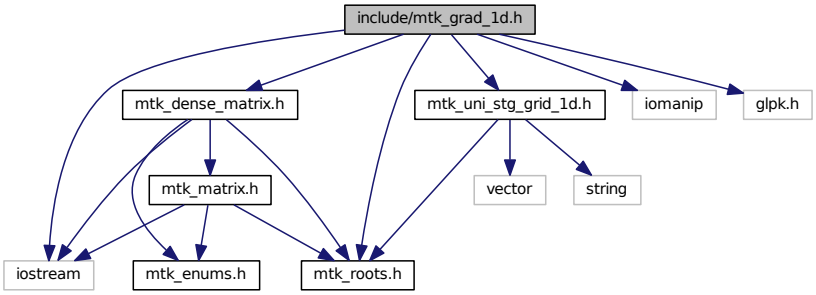
```
00102  public:
00123   static mtk::Real SolveSimplexAndCompare(
      mtk::Real *A,
00124                                           int nrows,
00125                                           int ncols,
00126                                           int kk,
00127                                           mtk::Real *hh,
00128                                           mtk::Real *qq,
00129                                           int robjective,
00130                                           mtk::Real mimetic_tol,
00131                                           int copy);
00132 };
00133 }
00134 #endif  // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_
```

## 17.27 include/mtk_grad_1d.h File Reference

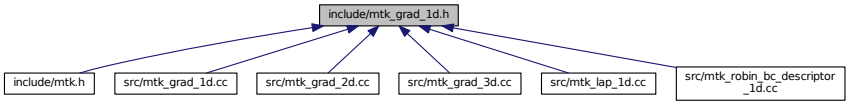
Includes the definition of the class Grad1D.

```
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk_grad_1d.h:




This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Grad1D

  *Implements a 1D mimetic gradient operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.27.1 Detailed Description

This class implements a 1D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_1d.h.

## 17.28 mtk_grad_1d.h

```
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00011 /*
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_GRAD_1D_H_
00058 #define MTK_INCLUDE_GRAD_1D_H_
00059
00060 #include <iostream>
```

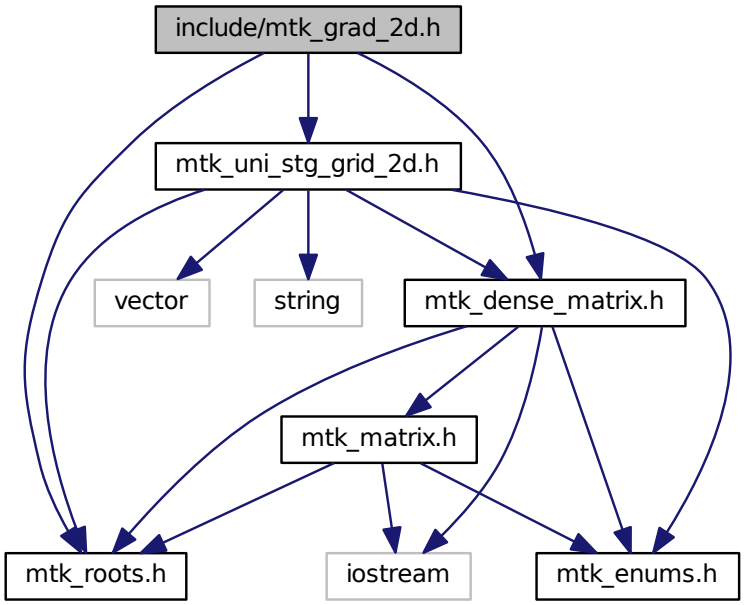
```
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Grad1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00085
00087   Grad1D();
00088
00094   Grad1D(const Grad1D &grad);
00095
00097   ~Grad1D();
00098
00104   bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00105                        Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112   int num_bndy_coeffs() const;
00113
00119   Real *coeffs_interior() const;
00120
00126   Real *weights_crs(void) const;
00127
00133   Real *weights_cbs(void) const;
00134
00140   DenseMatrix mim_bndy() const;
00141
00147   DenseMatrix ReturnAsDenseMatrix(Real west,
      Real east, int num_cells_x) const;
00148
00154   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00155
00161   DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
      const;
00162
00163  private:
00169   bool ComputeStencilInteriorGrid(void);
00170
00177   bool ComputeRationalBasisNullSpace(void);
00178
00184   bool ComputePreliminaryApproximations(void);
00185
00191   bool ComputeWeights(void);
00192
00198   bool ComputeStencilBoundaryGrid(void);
00199
00205   bool AssembleOperator(void);
00206
00207   int order_accuracy_;
00208   int dim_null_;
00209   int num_bndy_approxs_;
00210   int num_bndy_coeffs_;
00211   int gradient_length_;
00212   int minrow_;
00213   int row_;
00214
00215   DenseMatrix rat_basis_null_space_;
00216
00217   Real *coeffs_interior_;
00218   Real *prem_apps_;
00219   Real *weights_crs_;
00220   Real *weights_cbs_;
00221   Real *mim_bndy_;
00222   Real *gradient_;
00223
00224   Real mimetic_threshold_;
00225 };
00226 }
00227 #endif  // End of: MTK_INCLUDE_GRAD_1D_H_
```

## 17.29 include/mtk_grad_2d.h File Reference

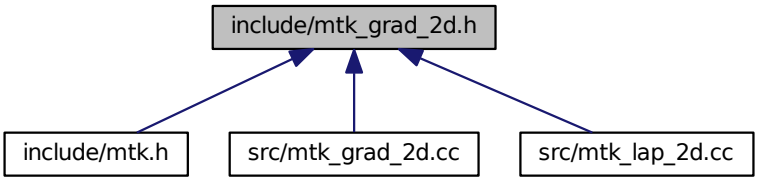
Includes the definition of the class Grad2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_grad_2d.h:




This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Grad2D

*Implements a 2D mimetic gradient operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.29.1 Detailed Description

This class implements a 2D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_2d.h.

## 17.30 mtk_grad_2d.h

```
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00011 /*
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00013 University. All rights reserved.
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
```

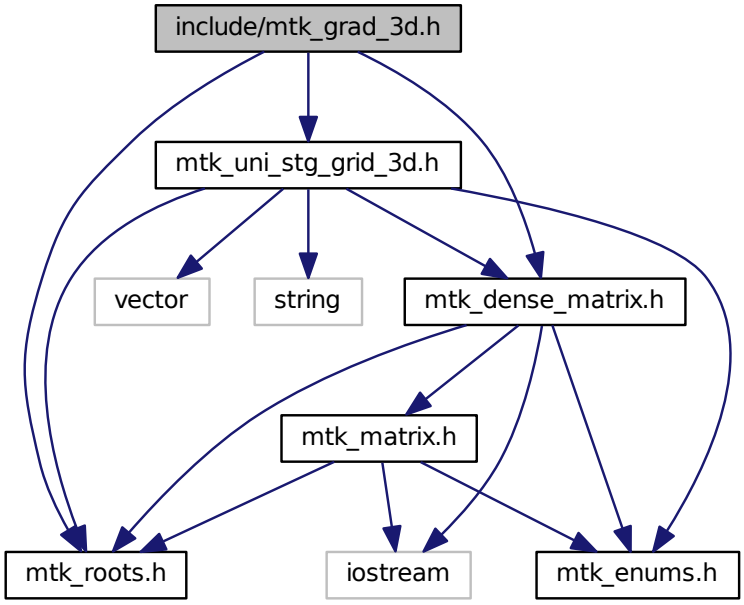
```
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_2D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Grad2D {
00077  public:
00079   Grad2D();
00080
00086   Grad2D(const Grad2D &grad);
00087
00089   ~Grad2D();
00090
00096   bool ConstructGrad2D(const UniStgGrid2D &grid,
00097                        int order_accuracy = kDefaultOrderAccuracy,
00098                        Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix gradient_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_GRAD_2D_H_
```

## 17.31 include/mtk_grad_3d.h File Reference

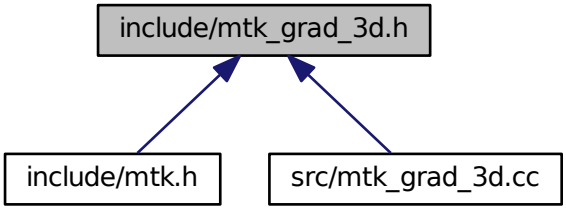
Includes the definition of the class Grad3D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_grad_3d.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::Grad3D

  *Implements a 3D mimetic gradient operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.31.1 Detailed Description

This class implements a 3D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_3d.h.

## 17.32 mtk_grad_3d.h

```
00001
00011 /*
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00013 University. All rights reserved.
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00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00029 other materials provided with the distribution.
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_3D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_3D_H_
00059
00060 #include "mtk_roots.h"
```

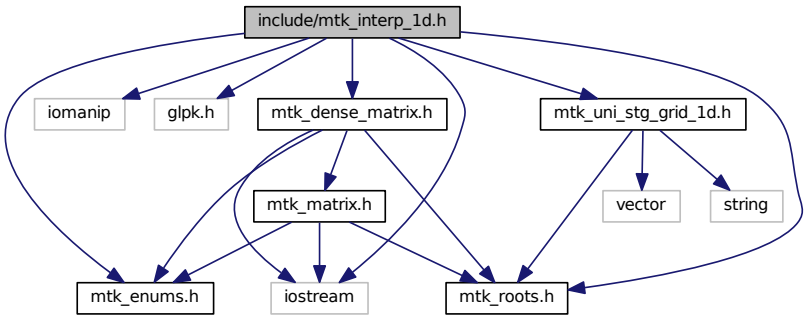
```
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_3d.h"
00063
00064 namespace mtk{
00065
00076 class Grad3D {
00077  public:
00079   Grad3D();
00080
00086   Grad3D(const Grad3D &grad);
00087
00089   ~Grad3D();
00090
00096   bool ConstructGrad3D(const UniStgGrid3D &grid,
00097                        int order_accuracy = kDefaultOrderAccuracy,
00098                        Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix gradient_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_GRAD_3D_H_
```

## 17.33 include/mtk_interp_1d.h File Reference

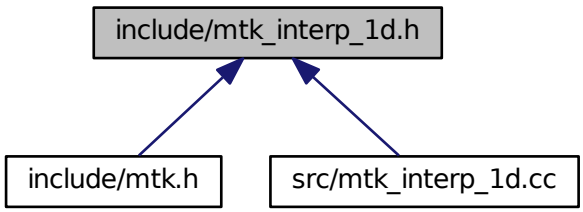
Includes the definition of the class Interp1D.

```
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk_interp_1d.h:



This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Interp1D

  *Implements a 1D interpolation operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

#### 17.33.1 Detailed Description

This class implements a 1D interpolation operator.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu
: Johnny Corbino - jcorbino at mail dot sdsu dot edu

Definition in file mtk_interp_1d.h.

## 17.34 mtk_interp_1d.h

```
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
```

```
00025 2. Redistributions of source code must be done through direct
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00056 */
00057
00058 #ifndef MTK_INCLUDE_INTERP_1D_H_
00059 #define MTK_INCLUDE_INTERP_1D_H_
00060
00061 #include <iostream>
00062 #include <iomanip>
00063
00064 #include "glpk.h"
00065
00066 #include "mtk_roots.h"
00067 #include "mtk_enums.h"
00068 #include "mtk_dense_matrix.h"
00069 #include "mtk_uni_stg_grid_1d.h"
00070
00071 namespace mtk {
00072
00082 class Interp1D {
00083  public:
00085   friend std::ostream& operator <<(std::ostream& stream, Interp1D &in);
00086
00088   Interp1D();
00089
00095   Interp1D(const Interp1D &interp);
00096
00098   ~Interp1D();
00099
00105   bool ConstructInterp1D(int order_accuracy =
      kDefaultOrderAccuracy,
00106                          mtk::DirInterp dir = SCALAR_TO_VECTOR);
00107
00113   Real *coeffs_interior() const;
00114
00120   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00121
00122  private:
00123   DirInterp dir_interp_;
00124
00125   int order_accuracy_;
00126
00127   Real *coeffs_interior_;
00128 };
00129 }
00130 #endif  // End of: MTK_INCLUDE_INTERP_1D_H_
```
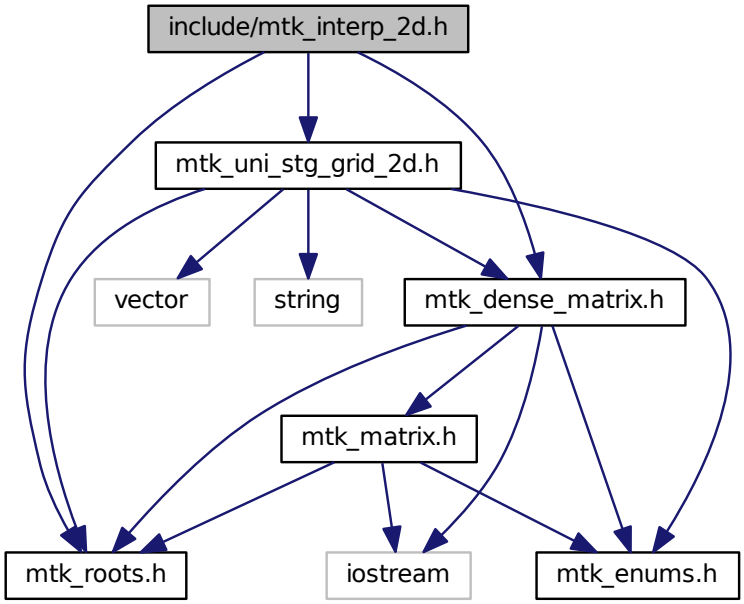

## 17.35 include/mtk_interp_2d.h File Reference

Includes the definition of the class Interp2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_interp_2d.h:




### Classes

- class mtk::Interp2D

  *Implements a 2D interpolation operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.35.1 Detailed Description

This class implements a 2D interpolation operator.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu
: Johnny Corbino - jcorbino at mail dot sdsu dot edu

Definition in file mtk_interp_2d.h.

## 17.36 mtk_interp_2d.h

```
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00056 */
00057
00058 #ifndef MTK_INCLUDE_MTK_INTERP_2D_H_
00059 #define MTK_INCLUDE_MTK_INTERP_2D_H_
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_dense_matrix.h"
00063 #include "mtk_uni_stg_grid_2d.h"
00064
00065 namespace mtk{
00066
00076 class Interp2D {
00077  public:
00079   Interp2D();
00080
00086   Interp2D(const Interp2D &interp);
00087
00089   ~Interp2D();
00090
00096   DenseMatrix ConstructInterp2D(const UniStgGrid2D &grid,
00097                                 int order_accuracy = kDefaultOrderAccuracy,
```

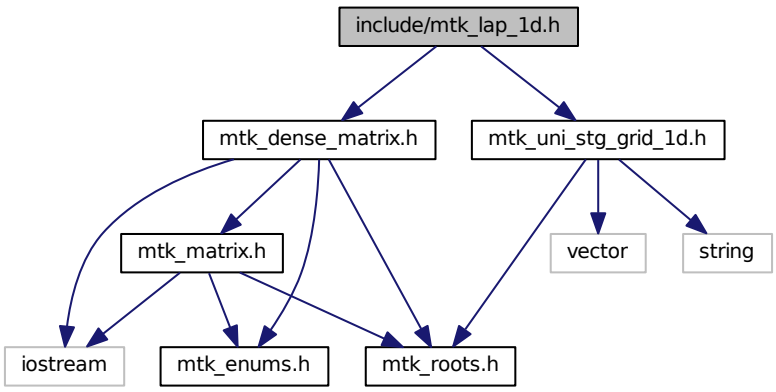
```
00098                             Real mimetic_threshold =
      kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix();
00106
00107  private:
00108   DenseMatrix interpolator_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_INTERP_2D_H_
```

## 17.37 include/mtk_lap_1d.h File Reference

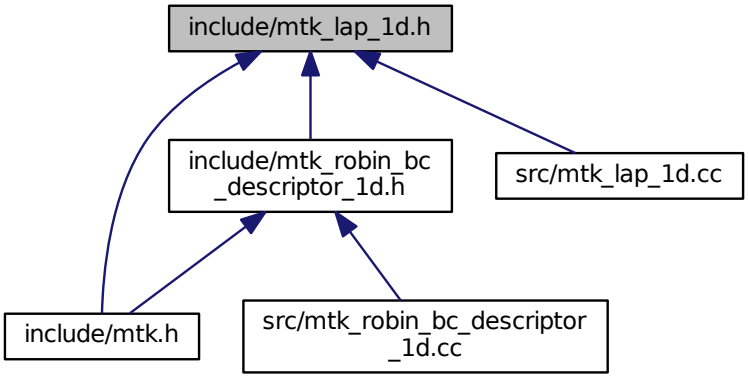
Includes the definition of the class Lap1D.

```
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk_lap_1d.h:



This graph shows which files directly or indirectly include this file:




### Classes

- class mtk::Lap1D

  *Implements a 1D mimetic Laplacian operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.37.1 Detailed Description

This class implements a 1D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_1d.h.

## 17.38 mtk_lap_1d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
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00055 */
00056
00057 #ifndef MTK_INCLUDE_LAP_1D_H_
00058 #define MTK_INCLUDE_LAP_1D_H_
00059
00060 #include "mtk_dense_matrix.h"
00061
00062 #include "mtk_uni_stg_grid_1d.h"
00063
00064 namespace mtk {
00065
00076 class Lap1D {
00077  public:
00079   friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00080
00082   Lap1D();
00083
00089   Lap1D(const Lap1D &lap);
00090
00092   ~Lap1D();
00093
00099   int order_accuracy() const;
00100
00106   Real mimetic_threshold() const;
00107
00113   Real delta() const;
00114
00120   bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00121                       Real mimetic_threshold = kDefaultMimeticThreshold);
00122
00128   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00129
00135   const mtk::Real* data(const UniStgGrid1D &grid) const;
00136
00137  private:
00138   int order_accuracy_;
00139   int laplacian_length_;
00140
00141   Real *laplacian_;
00142
00143   mutable Real delta_;
00144
00145   Real mimetic_threshold_;
```

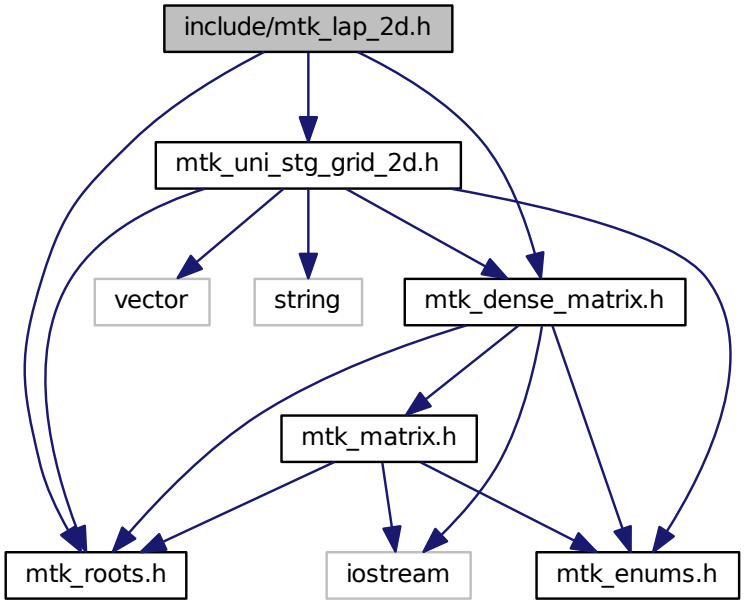
```
00146 };
00147 }
00148 #endif  // End of: MTK_INCLUDE_LAP_1D_H_
```

## 17.39 include/mtk_lap_2d.h File Reference

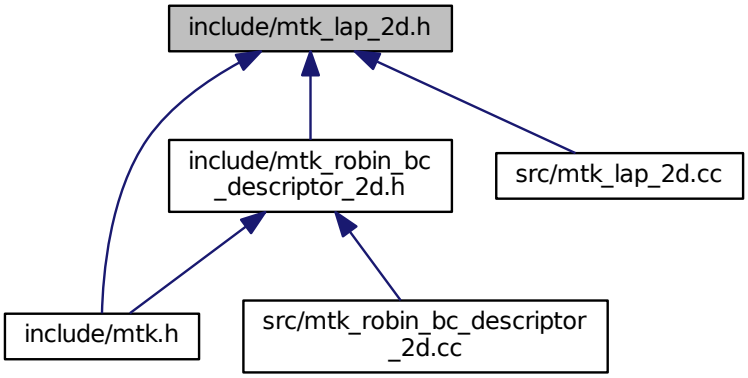
Includes the implementation of the class Lap2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_lap_2d.h:



This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::Lap2D

  *Implements a 2D mimetic Laplacian operator.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.39.1 Detailed Description

This class implements a 2D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_2d.h.

## 17.40 mtk_lap_2d.h

```
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```

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_LAP_2D_H_
00058 #define MTK_INCLUDE_MTK_LAP_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Lap2D {
00077  public:
00079   Lap2D();
00080
00086   Lap2D(const Lap2D &lap);
00087
00089   ~Lap2D();
00090
00096   bool ConstructLap2D(const UniStgGrid2D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00112   Real *data() const;
00113
00114  private:
00115   DenseMatrix laplacian_;
00116
00117   int order_accuracy_;
00118
00119   Real mimetic_threshold_;
00120 };
00121 }
00122 #endif  // End of: MTK_INCLUDE_MTK_LAP_2D_H_
```
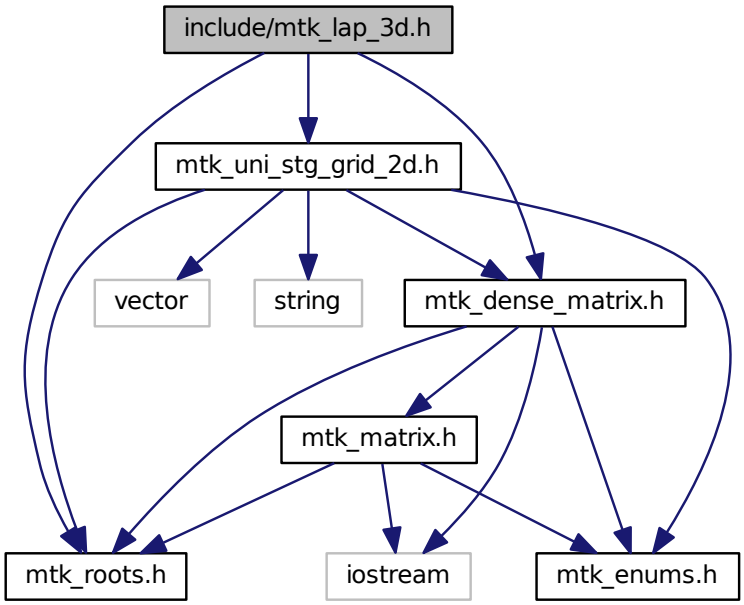

## 17.41 include/mtk_lap_3d.h File Reference

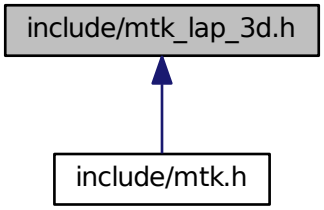
Includes the implementation of the class Lap3D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_lap_3d.h:




This graph shows which files directly or indirectly include this file:



### Classes

- class mtk::Lap3D

  *Implements a 3D mimetic Laplacian operator.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.41.1 Detailed Description

This class implements a 3D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_3d.h.

## 17.42 mtk_lap_3d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_LAP_3D_H_
00058 #define MTK_INCLUDE_MTK_LAP_3D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Lap3D {
00077  public:
00079   Lap3D();
00080
00086   Lap3D(const Lap3D &lap);
00087
00089   ~Lap3D();
00090
00096   bool ConstructLap3D(const UniStgGrid3D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00112   Real *data() const;
00113
00114  private:
00115   DenseMatrix laplacian_;
00116
00117   int order_accuracy_;
00118
00119   Real mimetic_threshold_;
00120 };
00121 }
00122 #endif  // End of: MTK_INCLUDE_MTK_LAP_3D_H_
```
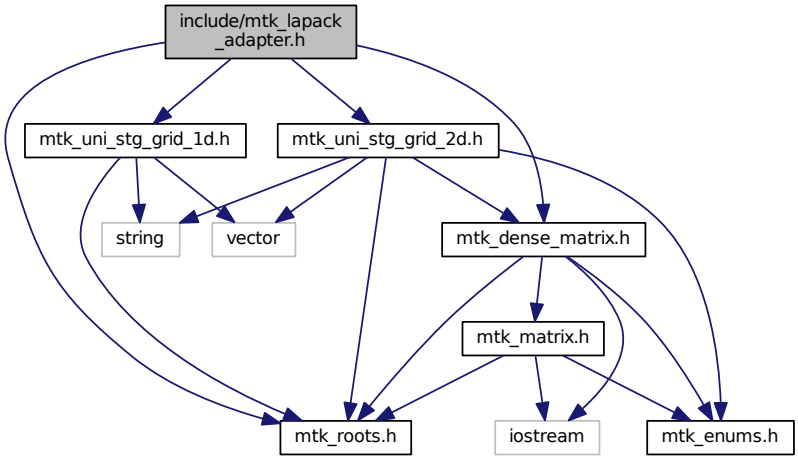

## 17.43 include/mtk_lapack_adapter.h File Reference

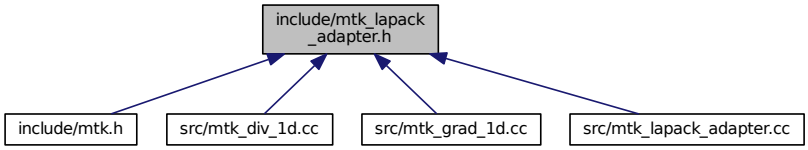
Adapter class for the LAPACK API.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_lapack_adapter.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::LAPACKAdapter

  *Adapter class for the LAPACK API.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.43.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the LAPACK.

The **LAPACK (Linear Algebra PACKage)** is written in Fortran 90 and provides routines for solving systems of simultaneous linear equations, least-squares solutions of linear systems of equations, eigenvalue problems, and singular value problems.

**See also**

http://www.netlib.org/lapack/

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lapack_adapter.h.

## 17.44 mtk_lapack_adapter.h

```
00001
00019 /*
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00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00066 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00067
00068 #include "mtk_roots.h"
00069 #include "mtk_dense_matrix.h"
00070 #include "mtk_uni_stg_grid_1d.h"
00071 #include "mtk_uni_stg_grid_2d.h"
00072
```

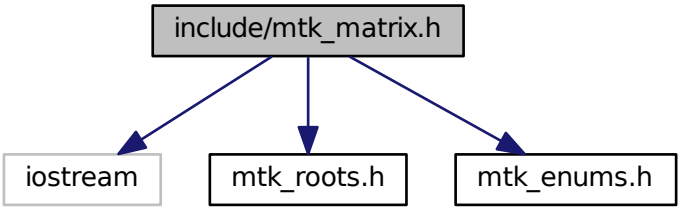
```
00073 namespace mtk {
00074
00093 class LAPACKAdapter {
00094  public:
00105   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00106                               mtk::Real *rhs);
00107
00118   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00119                               mtk::DenseMatrix &rr);
00120
00131   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00132                               mtk::UniStgGrid1D &rhs);
00133
00134
00145   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00146                               mtk::UniStgGrid2D &rhs);
00147
00159   static int SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00160                                          mtk::Real *ob_,
00161                                          int ob_ld_);
00162
00174   static mtk::DenseMatrix QRFactorDenseMatrix(
      DenseMatrix &matrix);
00175 };
00176 }
00177 #endif  // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_
```

## 17.45 include/mtk_matrix.h File Reference

Definition of the representation of a matrix in the MTK.

```
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"
```

Include dependency graph for mtk_matrix.h:




This graph shows which files directly or indirectly include this file:

### Classes

- class mtk::Matrix

  *Definition of the representation of a matrix in the MTK.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.45.1 Detailed Description

Definition of the representation for the matrices implemented in the MTK.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_matrix.h.

## 17.46 mtk_matrix.h

```
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00010 /*
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00015 are permitted provided that the following conditions are met:
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00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

```
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00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #ifndef MTK_INCLUDE_MATRIX_H_
00057 #define MTK_INCLUDE_MATRIX_H_
00058
00059 #include <iostream>
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_enums.h"
00063
00064 namespace mtk {
00065
00075 class Matrix {
00076  public:
00078   Matrix();
00079
00085   Matrix(const Matrix &in);
00086
00088   ~Matrix() noexcept ;
00089
00095   MatrixStorage storage() const noexcept;
00096
00102   MatrixOrdering ordering() const noexcept;
00103
00109   int num_rows() const noexcept;
00110
00116   int num_cols() const noexcept;
00117
00123   int num_values() const noexcept;
00124
00134   int ld() const noexcept;
00135
00141   int num_zero() const noexcept;
00142
00148   int num_non_zero() const noexcept;
00149
00157   int num_null() const noexcept;
00158
00166   int num_non_null() const noexcept;
00167
00173   int kl() const noexcept;
00174
00180   int ku() const noexcept;
00181
00187   int bandwidth() const noexcept;
00188
00196   Real abs_density() const noexcept;
00197
00205   Real rel_density() const noexcept;
00206
00214   Real abs_sparsity() const noexcept;
00215
00223   Real rel_sparsity() const noexcept;
00224
00232   void set_storage(const MatrixStorage &tt) noexcept;
00233
00241   void set_ordering(const MatrixOrdering &oo) noexcept;
00242
00248   void set_num_rows(const int &num_rows) noexcept;
00249
00255   void set_num_cols(const int &num_cols) noexcept;
00256
00262   void set_num_zero(const int &in) noexcept;
00263
00269   void set_num_null(const int &in) noexcept;
00270
00272   void IncreaseNumZero() noexcept;
00273
00275   void IncreaseNumNull() noexcept;
00276
00277  private:
00278   MatrixStorage storage_;
00279
00280   MatrixOrdering ordering_;
00281
00282   int num_rows_;
00283   int num_cols_;
00284   int num_values_;
00285   int ld_;
```

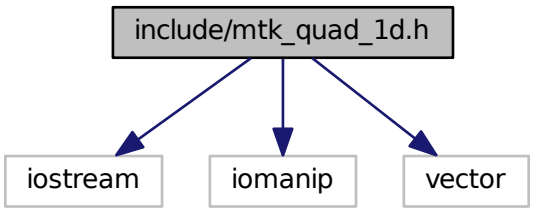
```
00286
00287   int num_zero_;
00288   int num_non_zero_;
00289   int num_null_;
00290   int num_non_null_;
00291
00292   int kl_;
00293   int ku_;
00294   int bandwidth_;
00295
00296   Real abs_density_;
00297   Real rel_density_;
00298   Real abs_sparsity_;
00299   Real rel_sparsity_;
00300 };
00301 }
00302 #endif  // End of: MTK_INCLUDE_MATRIX_H_
```

## 17.47 include/mtk_quad_1d.h File Reference

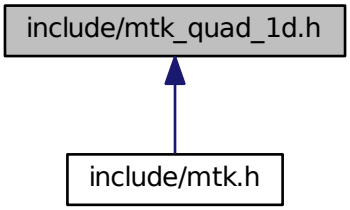
Includes the definition of the class Quad1D.

```
#include <iostream>
#include <iomanip>
#include <vector>
```

Include dependency graph for mtk_quad_1d.h:




This graph shows which files directly or indirectly include this file:



### Classes

- class mtk::Quad1D

  *Implements a 1D mimetic quadrature.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.47.1 Detailed Description

This class implements a 1D quadrature solver based on the mimetic discretization of the gradient operator.

**See also**

mtk::Grad1D

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Implement this class.

Definition in file mtk_quad_1d.h.

## 17.48 mtk_quad_1d.h

```
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00015 /*
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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #ifndef MTK_INCLUDE_QUAD_1D_H_
00062 #define MTK_INCLUDE_QUAD_1D_H_
00063
00064 #include <iostream>
00065 #include <iomanip>
00066
00067 #include <vector>
00068
00069 namespace mtk {
00070
00081 class Quad1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Quad1D &in);
00085
00087   Quad1D();
00088
00094   Quad1D(const Quad1D &quad);
00095
00097   ~Quad1D();
00098
00104   int degree_approximation() const;
00105
00111   Real *weights() const;
00112
00121   Real Integrate(Real (*Integrand)(Real xx), UniStgGrid1D grid) const;
00122
00123  private:
00124   int degree_approximation_;
00125
00126   std::vector<Real> weights_;
00127 };
00128 }
00129 #endif  // End of: MTK_INCLUDE_QUAD_1D_H_
```
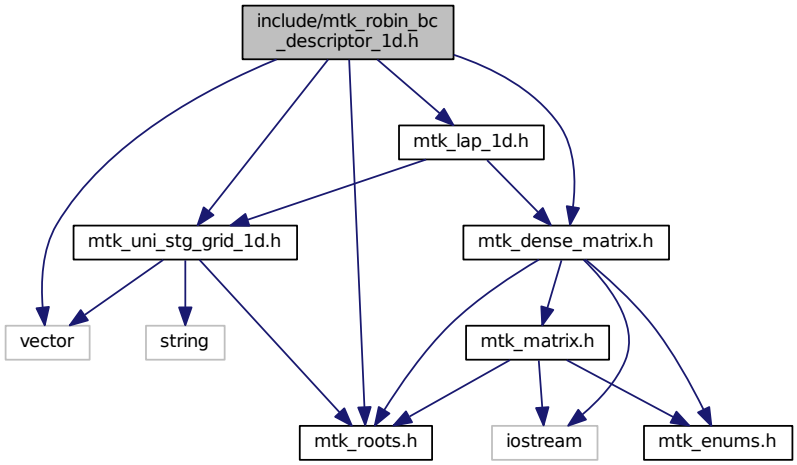

## 17.49 include/mtk_robin_bc_descriptor_1d.h File Reference

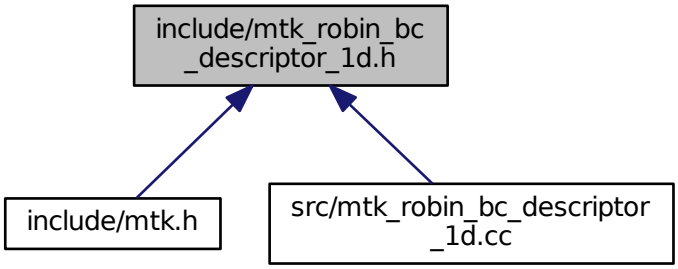
Impose Robin boundary conditions on the operators and on the grids.

```
#include <vector>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_lap_1d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_1d.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::RobinBCDescriptor1D

  *Impose Robin boundary conditions on the operators and on the grids.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Typedefs

- typedef Real(∗ mtk::CoefficientFunction0D )(const Real &tt)

  *A function of a BC coefficient evaluated on a 0D domain and time.*

### 17.49.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 1D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

In a 1D context ( $\partial\Omega = \{a,b\} \subset \mathbb{R}$), this condition can be written as follows:

$$\delta_a(a,t)u(a,t) - \eta_a(a,t)u'(a,t) = \beta_a(a,t),$$

$$\delta_b(b,t)u(b,t) + \eta_b(b,t)u'(b,t) = \beta_b(b,t).$$

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the condition in the grids.

#### See also

http://mathworld.wolfram.com/NormalVector.html

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_robin_bc_descriptor_1d.h.

## 17.50 mtk_robin_bc_descriptor_1d.h

```
00001
00043 /*
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00048 are permitted provided that the following conditions are met:
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00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
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```

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00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #include <vector>
00090
00091 #include "mtk_roots.h"
00092 #include "mtk_dense_matrix.h"
00093 #include "mtk_uni_stg_grid_1d.h"
00094 #include "mtk_lap_1d.h"
00095
00096 #ifndef MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
00097 #define MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
00098
00099 namespace mtk {
00111 typedef Real (*CoefficientFunction0D)(const Real &tt);
00112
00155 class RobinBCDescriptor1D {
00156  public:
00158   RobinBCDescriptor1D();
00159
00165   RobinBCDescriptor1D(const RobinBCDescriptor1D &desc);
00166
00168   ~RobinBCDescriptor1D() noexcept;
00169
00175   int highest_order_diff_west() const noexcept;
00176
00182   int highest_order_diff_east() const noexcept;
00183
00189   void PushBackWestCoeff(CoefficientFunction0D cw);
00190
00196   void PushBackEastCoeff(CoefficientFunction0D ce);
00197
00203   void set_west_condition(Real (*west_condition)(const
      Real &tt)) noexcept;
00204
00210   void set_east_condition(Real (*east_condition)(const
      Real &tt)) noexcept;
00211
00221   bool ImposeOnLaplacianMatrix(const Lap1D &lap,
00222                                DenseMatrix &matrix,
00223                                const Real &time = mtk::kZero) const;
00230   void ImposeOnGrid(UniStgGrid1D &grid, const Real &time =
      mtk::kZero) const;
00231
00232  private:
00233   int highest_order_diff_west_;
00234   int highest_order_diff_east_;
00235
00236   std::vector<CoefficientFunction0D> west_coefficients_;
00237   std::vector<CoefficientFunction0D> east_coefficients_;
00238
00239   Real (*west_condition_)(const Real &tt);
00240   Real (*east_condition_)(const Real &tt);
00241 };
00242 }
```

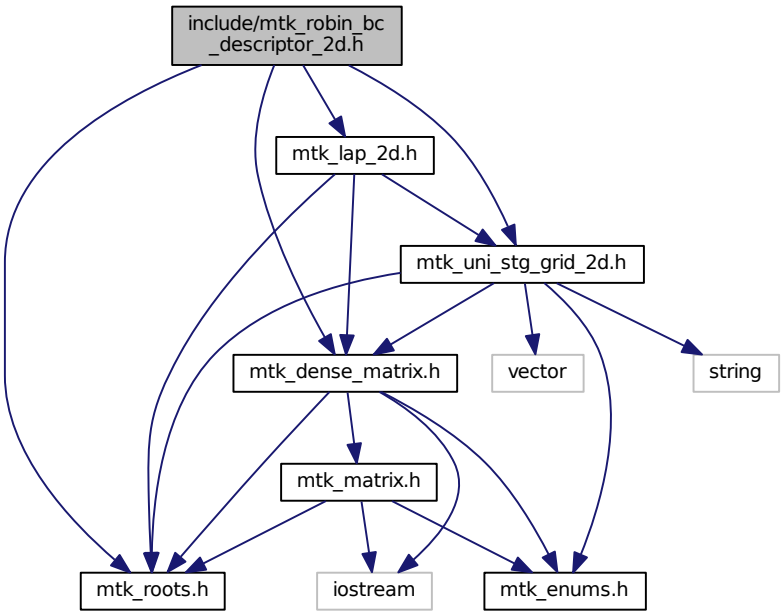
```
00243 #endif  // End of: MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
```

## 17.51 include/mtk_robin_bc_descriptor_2d.h File Reference

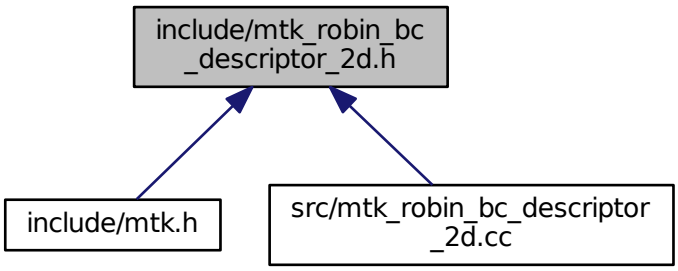
Impose Robin boundary conditions on the operators and on the grids.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_lap_2d.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_2d.h:



This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::RobinBCDescriptor2D

  *Impose Robin boundary conditions on the operators and on the grids.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

## Typedefs

- typedef Real(∗ mtk::CoefficientFunction1D )(const Real &xx, const Real &tt)

  *A function of a BC coefficient evaluated on a 1D domain and time.*

### 17.51.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

**See also**

http://mathworld.wolfram.com/NormalVector.html

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_robin_bc_descriptor_2d.h.

## 17.52 mtk_robin_bc_descriptor_2d.h

```
00001
00034 /*
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00036 University. All rights reserved.
00037
00038 Redistribution and use in source and binary forms, with or without modification,
00039 are permitted provided that the following conditions are met:
00040
00041 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00042 and a copy of the modified files should be reported once modifications are
00043 completed, unless these modifications are made through the project's GitHub
00044 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00045 should be developed and included in any deliverable.
00046
00047 2. Redistributions of source code must be done through direct
00048 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00049
00050 3. Redistributions in binary form must reproduce the above copyright notice,
00051 this list of conditions and the following disclaimer in the documentation and/or
00052 other materials provided with the distribution.
00053
00054 4. Usage of the binary form on proprietary applications shall require explicit
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00075 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00076 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00077 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00078 */
00079
00080 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00081 #define MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00082
00083 #include "mtk_roots.h"
00084 #include "mtk_dense_matrix.h"
00085 #include "mtk_lap_2d.h"
00086 #include "mtk_uni_stg_grid_2d.h"
00087
00088 namespace mtk{
00089
00097 typedef Real (*CoefficientFunction1D)(const Real &xx, const
      Real &tt);
00098
00132 class RobinBCDescriptor2D {
```

```
00133  public:
00135   RobinBCDescriptor2D();
00136
00142   RobinBCDescriptor2D(const RobinBCDescriptor2D &desc);
00143
00145   ~RobinBCDescriptor2D() noexcept;
00146
00152   int highest_order_diff_west() const noexcept;
00153
00159   int highest_order_diff_east() const noexcept;
00160
00166   int highest_order_diff_south() const noexcept;
00167
00173   int highest_order_diff_north() const noexcept;
00174
00181   void PushBackWestCoeff(CoefficientFunction1D cw);
00182
00189   void PushBackEastCoeff(CoefficientFunction1D ce);
00190
00197   void PushBackSouthCoeff(CoefficientFunction1D cs);
00198
00205   void PushBackNorthCoeff(CoefficientFunction1D cn);
00206
00213   void set_west_condition(Real (*west_condition)(const
      Real &yy,
00214                                                  const Real &tt)) noexcept;
00215
00222   void set_east_condition(Real (*east_condition)(const
      Real &yy,
00223                                                  const Real &tt)) noexcept;
00224
00231   void set_south_condition(Real (*south_condition)(const
      Real &xx,
00232                                                    const Real &tt)) noexcept;
00233
00240   void set_north_condition(Real (*north_condition)(const
      Real &xx,
00241                                                    const Real &tt)) noexcept;
00242
00251   bool ImposeOnLaplacianMatrix(const Lap2D &lap,
00252                                const UniStgGrid2D &grid,
00253                                DenseMatrix &matrix,
00254                                const Real &time = kZero) const;
00261   void ImposeOnGrid(UniStgGrid2D &grid, const Real &time =
      kZero) const;
00262
00263 private:
00272   bool ImposeOnSouthBoundaryNoSpace(const Lap2D &lap,
00273                                     const UniStgGrid2D &grid,
00274                                     DenseMatrix &matrix,
00275                                     const Real &time = kZero) const;
00284   bool ImposeOnNorthBoundaryNoSpace(const Lap2D &lap,
00285                                     const UniStgGrid2D &grid,
00286                                     DenseMatrix &matrix,
00287                                     const Real &time = kZero) const;
00296   bool ImposeOnWestBoundaryNoSpace(const Lap2D &lap,
00297                                    const UniStgGrid2D &grid,
00298                                    DenseMatrix &matrix,
00299                                    const Real &time = kZero) const;
00308   bool ImposeOnEastBoundaryNoSpace(const Lap2D &lap,
00309                                    const UniStgGrid2D &grid,
00310                                    DenseMatrix &matrix,
00311                                    const Real &time = kZero) const;
00320   bool ImposeOnSouthBoundaryWithSpace(const Lap2D &lap,
00321                                       const UniStgGrid2D &grid,
00322                                       DenseMatrix &matrix,
00323                                       const Real &time = kZero) const;
00332   bool ImposeOnNorthBoundaryWithSpace(const Lap2D &lap,
00333                                       const UniStgGrid2D &grid,
00334                                       DenseMatrix &matrix,
00335                                       const Real &time = kZero) const;
00344   bool ImposeOnWestBoundaryWithSpace(const Lap2D &lap,
00345                                      const UniStgGrid2D &grid,
00346                                      DenseMatrix &matrix,
00347                                      const Real &time = kZero) const;
00356   bool ImposeOnEastBoundaryWithSpace(const Lap2D &lap,
00357                                      const UniStgGrid2D &grid,
00358                                      DenseMatrix &matrix,
00359                                      const Real &time = kZero) const;
00360
00361   int highest_order_diff_west_;
```

```
00362   int highest_order_diff_east_;
00363   int highest_order_diff_south_;
00364   int highest_order_diff_north_;
00365
00366   std::vector<CoefficientFunction1D> west_coefficients_;
00367   std::vector<CoefficientFunction1D> east_coefficients_;
00368   std::vector<CoefficientFunction1D> south_coefficients_;
00369   std::vector<CoefficientFunction1D> north_coefficients_;
00370
00371   Real (*west_condition_)(const Real &xx, const Real &tt);
00372   Real (*east_condition_)(const Real &xx, const Real &tt);
00373   Real (*south_condition_)(const Real &yy, const Real &tt);
00374   Real (*north_condition_)(const Real &yy, const Real &tt);
00375 };
00376 }
00377 #endif  // End of: MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
```

## 17.53 include/mtk_roots.h File Reference

Fundamental definitions to be used across all classes of the MTK.

This graph shows which files directly or indirectly include this file:

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Typedefs

- typedef float mtk::Real

  *Users can simply change this to build a double- or single-precision MTK.*

### Variables

- const float mtk::kZero {0.0f}

  *MTK's zero defined according to selective compilation.*
- const float mtk::kOne {1.0f}

  *MTK's one defined according to selective compilation.*
- const float mtk::kTwo {2.0f}

  *MTK's two defined according to selective compilation.*
- const float mtk::kDefaultTolerance {1e-7f}

  *Considered tolerance for comparisons in numerical methods.*
- const int mtk::kDefaultOrderAccuracy {2}

  *Default order of accuracy for mimetic operators.*
- const float mtk::kDefaultMimeticThreshold {1e-6f}

  *Default tolerance for higher-order mimetic operators.*
- const int mtk::kCriticalOrderAccuracyDiv {8}

*At this order (and higher) we must use the CBSA to construct.*

- const int mtk::kCriticalOrderAccuracyGrad {10}

  *At this order (and higher) we must use the CBSA to construct.*

### 17.53.1 Detailed Description

This file contains the fundamental definitions that classes of the MTK rely on to be implemented. Examples of these definitions are the definition of fundamental data types, and global variables affecting the construction of mimetic operators, among others.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at sciences dot sdsu dot edu

**Todo** Documentation should (better?) capture effects from selective compilation.

**Todo** Test selective precision mechanisms.

Definition in file mtk_roots.h.

## 17.54 mtk_roots.h

```
00001
00017 /*
00018 Copyright (C) 2015, Computational Science Research Center, San Diego State
00019 University. All rights reserved.
00020
00021 Redistribution and use in source and binary forms, with or without modification,
00022 are permitted provided that the following conditions are met:
00023
00024 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00025 and a copy of the modified files should be reported once modifications are
00026 completed, unless these modifications are made through the project's GitHub
00027 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00028 should be developed and included in any deliverable.
00029
00030 2. Redistributions of source code must be done through direct
00031 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00058 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00059 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
```

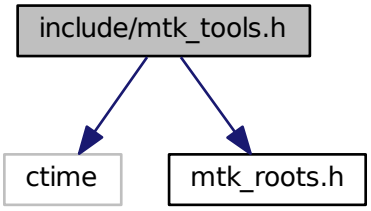
```
00060 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00061 */
00062
00063 #ifndef MTK_INCLUDE_ROOTS_H_
00064 #define MTK_INCLUDE_ROOTS_H_
00065
00071 namespace mtk {
00072
00080 #ifdef MTK_PRECISION_DOUBLE
00081 typedef double Real;
00082 #else
00083 typedef float Real;
00084 #endif
00085
00111 #ifdef MTK_PRECISION_DOUBLE
00112 const double kZero{0.0};
00113 const double kOne{1.0};
00114 const double kTwo{2.0};
00115 #else
00116 const float kZero{0.0f};
00117 const float kOne{1.0f};
00118 const float kTwo{2.0f};
00119 #endif
00120
00128 #ifdef MTK_PRECISION_DOUBLE
00129 const double kDefaultTolerance{1e-7};
00130 #else
00131 const float kDefaultTolerance{1e-7f};
00132 #endif
00133
00143 const int kDefaultOrderAccuracy{2};
00144
00154 #ifdef MTK_PRECISION_DOUBLE
00155 const double kDefaultMimeticThreshold{1e-6};
00156 #else
00157 const float kDefaultMimeticThreshold{1e-6f};
00158 #endif
00159
00167 const int kCriticalOrderAccuracyDiv{8};
00168
00176 const int kCriticalOrderAccuracyGrad{10};
00177 }
00178 #endif  // End of: MTK_INCLUDE_ROOTS_H_
```

## 17.55 include/mtk_tools.h File Reference

Tool manager class.

```
#include <ctime>
#include "mtk_roots.h"
```

Include dependency graph for mtk_tools.h:



This graph shows which files directly or indirectly include this file:

## Classes

- class mtk::Tools

  *Tool manager class.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.55.1 Detailed Description

Basic utilities.

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

#### Note

Performance Tip 8.1. If they do not need to be modified by the called function, pass large objects using pointers to constant data or references to constant data, to obtain the performance benefits of pass-by-reference.

Definition in file mtk_tools.h.

## 17.56 mtk_tools.h

```
00001
00014 /*
00015 Copyright (C) 2015, Computational Science Research Center, San Diego State
00016 University. All rights reserved.
00017
00018 Redistribution and use in source and binary forms, with or without modification,
00019 are permitted provided that the following conditions are met:
00020
00021 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00022 and a copy of the modified files should be reported once modifications are
00023 completed, unless these modifications are made through the project's GitHub
00024 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00025 should be developed and included in any deliverable.
00026
00027 2. Redistributions of source code must be done through direct
00028 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00030 3. Redistributions in binary form must reproduce the above copyright notice,
00031 this list of conditions and the following disclaimer in the documentation and/or
00032 other materials provided with the distribution.
00033
00034 4. Usage of the binary form on proprietary applications shall require explicit
00035 prior written permission from the the copyright holders, and due credit should
00036 be given to the copyright holders.
```

```
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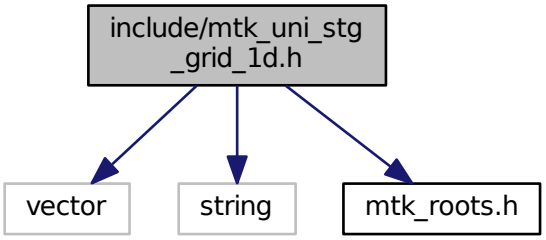
00055 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00056 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00057 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00058 */
00059
00060 #ifndef MTK_INCLUDE_TOOLS_H_
00061 #define MTK_INCLUDE_TOOLS_H_
00062
00063 #include <ctime>
00064
00065 #include "mtk_roots.h"
00066
00067 namespace mtk {
00068
00078 class Tools {
00079  public:
00090   static void Prevent(const bool complement,
00091                       const char *const fname,
00092                       int lineno,
00093                       const char *const fxname) noexcept;
00094
00100   static void BeginUnitTestNo(const int &nn) noexcept;
00101
00107   static void EndUnitTestNo(const int &nn) noexcept;
00108
00114   static void Assert(const bool &condition) noexcept;
00115
00116  private:
00117   static int test_number_;
00118
00119   static Real duration_;
00120
00121   static clock_t begin_time_;
00122 };
00123 }
00124 #endif  // End of: MTK_INCLUDE_TOOLS_H_
```

## 17.57 include/mtk_uni_stg_grid_1d.h File Reference

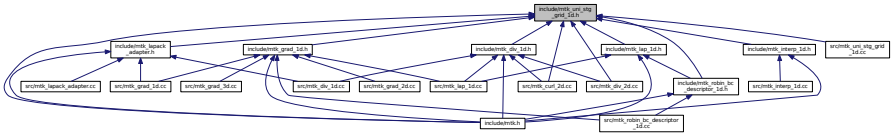
Definition of an 1D uniform staggered grid.

```
#include <vector>
#include <string>
#include "mtk_roots.h"
```

Include dependency graph for mtk_uni_stg_grid_1d.h:




This graph shows which files directly or indirectly include this file:



## Classes

- class mtk::UniStgGrid1D

  *Uniform 1D Staggered Grid.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.57.1 Detailed Description

Definition of an 1D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Create overloaded binding routines that read data from files.

Definition in file mtk_uni_stg_grid_1d.h.

## 17.58 mtk_uni_stg_grid_1d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
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00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_1D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_1D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065
00066 namespace mtk {
00067
00077 class UniStgGrid1D {
00078  public:
00080   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid1D &in);
00081
00083   UniStgGrid1D();
00084
00090   UniStgGrid1D(const UniStgGrid1D &grid);
00091
00102   UniStgGrid1D(const Real &west_bndy_x,
00103                const Real &east_bndy_x,
00104                const int &num_cells_x,
00105                const mtk::FieldNature &nature = mtk::SCALAR);
00106
00108   ~UniStgGrid1D();
00109
00115   Real west_bndy_x() const;
00116
00122   Real east_bndy_x() const;
00123
00129   Real delta_x() const;
00130
```

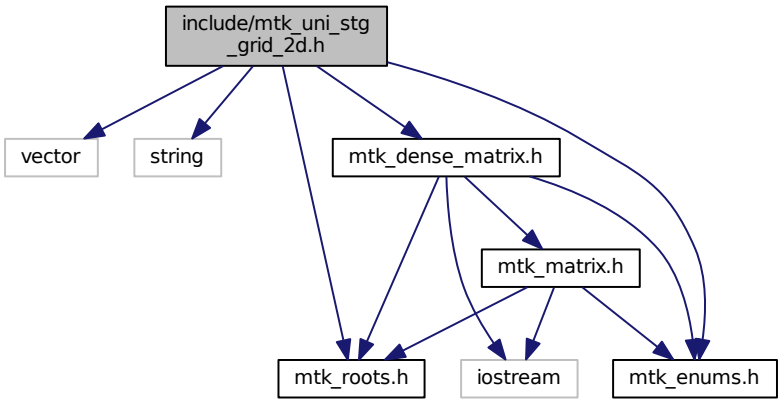
```
00138   const Real *discrete_domain_x() const;
00139
00147   Real *discrete_field();
00148
00154   int num_cells_x() const;
00155
00161   void BindScalarField(Real (*ScalarField)(const Real &xx));
00162
00173   void BindVectorField(Real (*VectorField)(Real xx));
00174
00186   bool WriteToFile(std::string filename,
00187                    std::string space_name,
00188                    std::string field_name) const;
00189
00190  private:
00191   FieldNature nature_;
00192
00193   std::vector<Real> discrete_domain_x_;
00194   std::vector<Real> discrete_field_;
00195
00196   Real west_bndy_x_;
00197   Real east_bndy_x_;
00198   Real num_cells_x_;
00199   Real delta_x_;
00200 };
00201 }
00202 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_
```

## 17.59 include/mtk_uni_stg_grid_2d.h File Reference

Definition of an 2D uniform staggered grid.

```
#include <vector>
#include <string>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
```

Include dependency graph for mtk_uni_stg_grid_2d.h:



This graph shows which files directly or indirectly include this file:

## Classes

- class mtk::UniStgGrid2D

  *Uniform 2D Staggered Grid.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.59.1 Detailed Description

Definition of an 2D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Create overloaded binding routines that read data from files.

Definition in file mtk_uni_stg_grid_2d.h.

## 17.60 mtk_uni_stg_grid_2d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
```

```
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_2D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_2D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_enums.h"
00066 #include "mtk_dense_matrix.h"
00067
00068 namespace mtk {
00069
00079 class UniStgGrid2D {
00080  public:
00082   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid2D &in);
00083
00085   UniStgGrid2D();
00086
00092   UniStgGrid2D(const UniStgGrid2D &grid);
00093
00107   UniStgGrid2D(const Real &west_bndy_x,
00108                const Real &east_bndy_x,
00109                const int &num_cells_x,
00110                const Real &south_bndy_y,
00111                const Real &north_bndy_y,
00112                const int &num_cells_y,
00113                const mtk::FieldNature &nature =
      mtk::SCALAR);
00114
00116   ~UniStgGrid2D();
00117
00125   const Real *discrete_domain_x() const;
00126
00134   const Real *discrete_domain_y() const;
00135
00141   Real *discrete_field();
00142
00150   FieldNature nature() const;
00151
00157   Real west_bndy() const;
00158
00164   Real east_bndy() const;
00165
00171   int num_cells_x() const;
00172
00178   Real delta_x() const;
00179
00185   Real south_bndy() const;
00186
00192   Real north_bndy() const;
00193
00199   int num_cells_y() const;
00200
00206   Real delta_y() const;
00207
00213   bool Bound() const;
00214
00220   int Size() const;
```

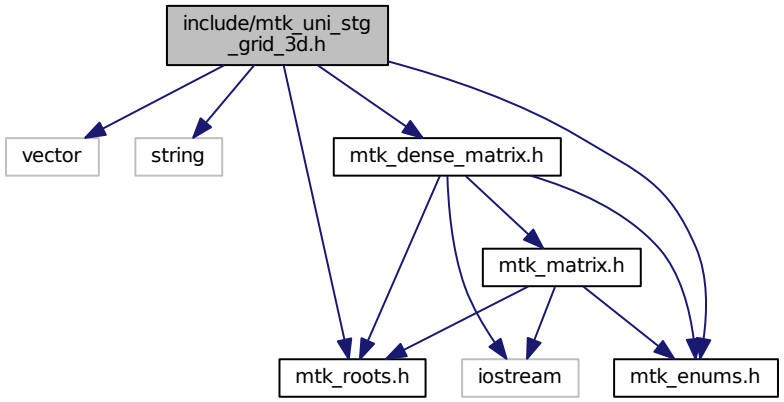
```
00221
00227   void BindScalarField(Real (*ScalarField)(const Real &xx, const
      Real &yy));
00228
00242   void BindVectorField(Real (*VectorFieldPComponent)(const
      Real &xx,
00243                                                      const Real &yy),
00244                        Real (*VectorFieldQComponent)(const Real &xx,
00245                                                      const Real &yy));
00246
00259   bool WriteToFile(std::string filename,
00260                    std::string space_name_x,
00261                    std::string space_name_y,
00262                    std::string field_name) const;
00263
00264  private:
00276   void BindVectorFieldPComponent(
00277     Real (*VectorFieldPComponent)(const Real &xx, const Real &yy));
00278
00290   void BindVectorFieldQComponent(
00291     Real (*VectorFieldQComponent)(const Real &xx, const Real &yy));
00292
00293   std::vector<Real> discrete_domain_x_;
00294   std::vector<Real> discrete_domain_y_;
00295   std::vector<Real> discrete_field_;
00296
00297   FieldNature nature_;
00298
00299   Real west_bndy_;
00300   Real east_bndy_;
00301   int num_cells_x_;
00302   Real delta_x_;
00303
00304   Real south_bndy_;
00305   Real north_bndy_;
00306   int num_cells_y_;
00307   Real delta_y_;
00308 };
00309 }
00310 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_2D_H_
```

## 17.61 include/mtk_uni_stg_grid_3d.h File Reference

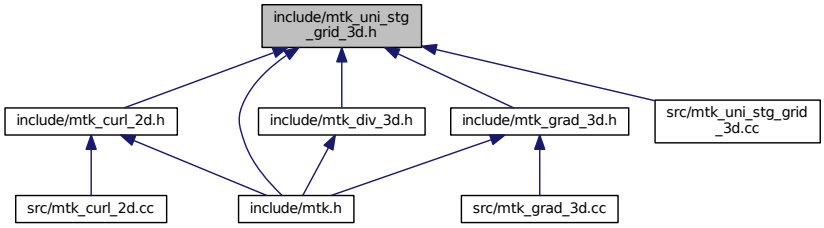
Definition of an 3D uniform staggered grid.

```
#include <vector>
#include <string>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
```

Include dependency graph for mtk_uni_stg_grid_3d.h:




This graph shows which files directly or indirectly include this file:




## Classes

- class mtk::UniStgGrid3D

  *Uniform 3D Staggered Grid.*

## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.61.1 Detailed Description

Definition of an 3D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Create overloaded binding routines that read data from files.

Definition in file mtk_uni_stg_grid_3d.h.

## 17.62 mtk_uni_stg_grid_3d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_3D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_3D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_enums.h"
00066 #include "mtk_dense_matrix.h"
00067
00068 namespace mtk {
00069
00079 class UniStgGrid3D {
00080  public:
00082   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid3D &in);
00083
00085   UniStgGrid3D();
00086
```

```
00092   UniStgGrid3D(const UniStgGrid3D &grid);
00093
00110   UniStgGrid3D(const Real &west_bndy_x,
00111                const Real &east_bndy_x,
00112                const int &num_cells_x,
00113                const Real &south_bndy_y,
00114                const Real &north_bndy_y,
00115                const int &num_cells_y,
00116                const Real &bottom_bndy_z,
00117                const Real &top_bndy_z,
00118                const int &num_cells_z,
00119                const mtk::FieldNature &nature =
      mtk::SCALAR);
00120
00122   ~UniStgGrid3D();
00123
00131   const Real *discrete_domain_x() const;
00132
00140   const Real *discrete_domain_y() const;
00141
00149   const Real *discrete_domain_z() const;
00150
00156   Real *discrete_field();
00157
00165   FieldNature nature() const;
00166
00172   Real west_bndy() const;
00173
00179   Real east_bndy() const;
00180
00186   int num_cells_x() const;
00187
00193   Real delta_x() const;
00194
00200   Real south_bndy() const;
00201
00207   Real north_bndy() const;
00208
00214   int num_cells_y() const;
00215
00221   Real delta_y() const;
00222
00228   Real bottom_bndy() const;
00229
00235   Real top_bndy() const;
00236
00242   int num_cells_z() const;
00243
00249   Real delta_z() const;
00250
00256   bool Bound() const;
00257
00263   int Size() const;
00264
00270   void BindScalarField(
00271     Real (*ScalarField)(const Real &xx, const Real &yy, const Real &zz));
00272
00289   void BindVectorField(Real (*VectorFieldPComponent)(const
      Real &xx,
00290                                                      const Real &yy,
00291                                                      const Real &zz),
00292                        Real (*VectorFieldQComponent)(const Real &xx,
00293                                                      const Real &yy,
00294                                                      const Real &zz),
00295                        Real (*VectorFieldRComponent)(const Real &xx,
00296                                                      const Real &yy,
00297                                                      const Real &zz));
00298
00312   bool WriteToFile(std::string filename,
00313                    std::string space_name_x,
00314                    std::string space_name_y,
00315                    std::string space_name_z,
00316                    std::string field_name) const;
00317
00318  private:
00331   void BindVectorFieldPComponent(
00332     Real (*VectorFieldPComponent)(const Real &xx,
00333                                   const Real &yy,
00334                                   const Real &zz));
00335
00348   void BindVectorFieldQComponent(
```

```
00349     Real (*VectorFieldQComponent)(const Real &xx,
00350                                     const Real &yy,
00351                                     const Real &zz));
00352
00365   void BindVectorFieldRComponent(
00366     Real (*VectorFieldRComponent)(const Real &xx,
00367                                     const Real &yy,
00368                                     const Real &zz));
00369
00370   std::vector<Real> discrete_domain_x_;
00371   std::vector<Real> discrete_domain_y_;
00372   std::vector<Real> discrete_domain_z_;
00373   std::vector<Real> discrete_field_;
00374
00375   FieldNature nature_;
00376
00377   Real west_bndy_;
00378   Real east_bndy_;
00379   int num_cells_x_;
00380   Real delta_x_;
00381
00382   Real south_bndy_;
00383   Real north_bndy_;
00384   int num_cells_y_;
00385   Real delta_y_;
00386
00387   Real bottom_bndy_;
00388   Real top_bndy_;
00389   int num_cells_z_;
00390   Real delta_z_;
00391 };
00392 }
00393 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_3D_H_
```

## 17.63 Makefile.inc File Reference

## 17.64 Makefile.inc

```
00001 # Makefile setup file for the MTK.
00002
00003 SHELL := /bin/bash
00004
00005 # Please set the following variables up:
00006
00007 #   1. Absolute path to base directory of the MTK.
00008 #   ____________________________________________________________
00009
00010 BASE = /home/esanchez/Dropbox/MTK
00011
00012 #   2. The machine (platform) identifier and required machine precision.
00013 #   ____________________________________________________________
00014
00015 # Options are:
00016 # - LINUX: A LINUX box installation.
00017 # - OSX: Uses OS X optimized solvers.
00018
00019 PLAT = LINUX
00020
00021 # Options are:
00022 # - SINGLE: Use 4 B floating point numbers.
00023 # - DOUBLE: Use 8 B floating point numbers.
00024
00025 PRECISION = DOUBLE
00026
00027 #   3. Optimized solvers and operations by means of ATLAS in Linux?
00028 #   ____________________________________________________________
00029
00030 # If you have selected OSX in step 1, then you don't need to worry about this.
00031
00032 # Options are ON xor OFF:
00033
00034 ATL_OPT = OFF
00035
00036 #   4. Paths to dependencies (header files for compiling).
00037 #   ____________________________________________________________
```

```
00038
00039 # GLPK include path (soon to go):
00040
00041 GLPK_INC = $(HOME)/Libraries/glpk-4.35/include
00042
00043 # Linux: If ATLAS optimization is ON, users should only provide the path to
00044 # ATLAS:
00045
00046 ATLAS_INC = $(HOME)/Libraries/ATLAS_3.8.4-CORE/include
00047
00048 # OS X: Do nothing.
00049
00050 #   5. Paths to dependencies (archive files for (static) linking).
00051 #   ______________________________________________________________
00052
00053 # GLPK linking path (soon to go):
00054
00055 GLPK_LIB = $(HOME)/Libraries/glpk-4.35/lib/lib64/libglpk.a
00056
00057 # If optimization is OFF, then provide the paths for:
00058
00059 BLAS_LIB = $(HOME)/Libraries/BLAS-3.5.0/libblas.a
00060 LAPACK_LIB = $(HOME)/Libraries/lapack-3.5.0/liblapack.a
00061
00062 # WARNING: Vendor libraries should be used whenever they are available.
00063
00064 # However, if optimization is ON, please provide the path the ATLAS' archive:
00065
00066 ATLAS_LIB   = $(HOME)/Libraries/ATLAS_3.8.4-CORE/ATLAS_3.8.4-BUILD-Citadel/lib
00067
00068 #   6. Compiler and its flags.
00069 #   __________________________
00070
00071 CC = g++
00072
00073 # Selective Verbose Execution for Quick Debugging. Options are defined per
00074 # concern, and per data hierarchy on each concern.
00075
00076 # 0: NO verbose at all.
00077
00078 # 1: Enable verbose down to the 7th concern: messages.
00079 # 2: Enable verbose down to the 7th concern: messages + scalar results.
00080 # 3: Enable verbose down to the 7th concern. 1.1. + array results.
00081 # 4: Enable verbose down to the 7th concern. 1.2. + matrix results.
00082
00083 # 5: Enable verbose down to the 6th concern: messages.
00084 # 6: Enable verbose down to the 6th concern: messages + scalar results.
00085 # 7: Enable verbose down to the 6th concern. 2.1. + array results.
00086 # 8: Enable verbose down to the 6th concern. 2.2. + matrix results.
00087
00088 # 9: Enable verbose down to the 5th concern: messages.
00089 # 10: Enable verbose down to the 5th concern: messages + scalar results.
00090 # 11: Enable verbose down to the 5th concern. 3.1. + array results.
00091 # 12: Enable verbose down to the 5th concern. 3.2. + matrix results.
00092
00093 # 13: Enable verbose down to the 4th concern: messages.
00094 # 14: Enable verbose down to the 4th concern: messages + scalar results.
00095 # 15: Enable verbose down to the 4th concern. 4.1. + array results.
00096 # 16: Enable verbose down to the 4th concern. 4.2. + matrix results.
00097
00098 VERBOSE_LEVEL = 16
00099
00100 # Enable preventions. In the MTK, methods first validate their required
00101 # pre-conditions in run-time. Similarly, in many points throughout the MTK
00102 # codebase, different sanity checks are performed, as well. If this symbol is
00103 # defined to be 0, the MTK will # perform no validations to enhance execution
00104 # performance. Options are:
00105 # - YES.
00106 # - NO.
00107
00108 PERFORM_PREVENTIONS = YES
00109
00110 # Flags recommended for release code:
00111
00112 CCFLAGS = -Wall -Werror -O3
00113
00114 # Flags recommended for debugging code:
00115
00116 CCFLAGS = -Wall -Werror -g
00117
00118 #   7. Archiver, its flags, and ranlib:
```

```
00119 #   ____________________________________________________________________
00120
00121 ARCH      = ar
00122 ARCHFLAGS = cr
00123
00124 # If your system does not have "ranlib" then set: "RANLIB = echo":
00125
00126 RANLIB = echo
00127
00128 # But, if possible:
00129
00130 RANLIB = ranlib
00131
00132 #   8. Valgrind's memcheck options (optional):
00133 #   ____________________________________________________________________
00134
00135 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00136   --track-origins=yes --freelist-vol=20000000
00137
00138 # Done! User, please, do not mess with the definitions from this point on.
00139
00140 #   ____________________________________________________________________
00141 #   ____________________________________________________________________
00142 #   ____________________________________________________________________
00143
00144 #   MTK-related.
00145 #   ____________________________________________________________________
00146
00147 SRC       = $(BASE)/src
00148 INCLUDE   = $(BASE)/include
00149 LIB       = $(BASE)/lib
00150 MTK_LIB   = $(LIB)/libmtk.a
00151 TESTS     = $(BASE)/tests
00152 EXAMPLES  = $(BASE)/examples
00153
00154 #   Compiling-related.
00155 #   ____________________________________________________________________
00156
00157 CCFLAGS += -std=c++11 -fPIC \
00158   -DMTK_VERBOSE_LEVEL=$(VERBOSE_LEVEL) -I$(INCLUDE) -c
00159
00160 ifeq ($(PRECISION),DOUBLE)
00161   CCFLAGS += -DMTK_PRECISION_DOUBLE
00162 else
00163   CCFLAGS += -DMTK_PRECISION_SINGLE
00164 endif
00165
00166 ifeq ($(PERFORM_PREVENTIONS),YES)
00167   CCFLAGS += -DMTK_PERFORM_PREVENTIONS
00168 endif
00169
00170 # Only the GLPK is included because the other dependencies are coded in Fortran.
00171
00172 ifeq ($(ATL_OPT),ON)
00173   CCFLAGS  += -I$(GLPK_INC) $(ATLAS_INC)
00174 else
00175   CCFLAGS  += -I$(GLPK_INC)
00176 endif
00177
00178 #   Linking-related.
00179 #   ____________________________________________________________________
00180
00181 NOOPT_LIBS  = $(LAPACK_LIB) $(BLAS_LIB) -lm $(GLPK_LIB) -lstdc++
00182
00183 OPT_LIBS    = -L$(ATLAS_LIB) -latlas -llapack -lblas -lm -latlas -lstdc++
00184
00185 ifeq ($(PLAT),OSX)
00186   LINKER  = g++
00187   LINKER  += -framework Accelerate $(GLPK_LIB) $(MTK_LIB)
00188 else
00189   ifeq ($(ATL_OPT),ON)
00190     LINKER  = g++
00191     LIBS = $(MTK_LIB)
00192     LIBS += $(OPT_LIBS)
00193   else
00194     LINKER  = gfortran
00195     LIBS = $(MTK_LIB)
00196     LIBS += $(NOOPT_LIBS)
00197   endif
00198 endif
00199
```

```
00200 #   Documentation-related.
00201 #   ____________________________________________________________________
00202
00203 DOCGEN      = doxygen
00204 DOCFILENAME = doc_config.dxcf
00205 DOC         = $(BASE)/doc
00206 DOCFILE     = $(BASE)/$(DOCFILENAME)
```

## 17.65 README.md File Reference

## 17.66 README.md

```
00001 # The Mimetic Methods Toolkit (MTK)
00002
00003 By: **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu**
00004
00005 ## 1. Description
00006
00007 We define numerical methods that are based on discretizations preserving the
00008 properties of their continuum counterparts to be **mimetic**.
00009
00010 The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical
00011 methods. It is arranged as a set of classes for **mimetic quadratures**,
00012 **mimetic interpolation**, and **mimetic finite differences** methods for the
00013 numerical solution of ordinary and partial differential equations.
00014
00015 ## 2. Dependencies
00016
00017 This README assumes all of these dependencies are installed in the following
00018 folder:
00019
00020 ```
00021 $(HOME)/Libraries/
00022 ```
00023
00024 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00025 routines for the internal computation on some of the layers. However, ATLAS
00026 requires both BLAS and LAPACK in order to create their optimized distributions.
00027 Therefore, the following dependencies tree arises:
00028
00029 ### For Linux:
00030
00031 1. LAPACK - Available from: http://www.netlib.org/lapack/
00032   1. BLAS - Available from: http://www.netlib.org/blas/
00033
00034 2. GLPK - Available from: https://www.gnu.org/software/glpk/
00035
00036 3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00037   1. LAPACK - Available from: http://www.netlib.org/lapack/
00038     1. BLAS - Available from: http://www.netlib.org/blas
00039
00040 4. (Optional) Valgrind - Available from: http://valgrind.org/
00041
00042 5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00043
00044 ### For OS X:
00045
00046 1. GLPK - Available from: https://www.gnu.org/software/glpk/
00047
00048 ## 3. Installation
00049
00050 ### PART 1. CONFIGURATION OF THE MAKEFILE.
00051
00052 The following steps are required to build and test the MTK. Please use the
00053 accompanying `Makefile.inc` file, which should provide a solid template to
00054 start with. The following command provides help on the options for make:
00055
00056 ```
00057 $ make help
00058 -----
00059 Makefile for the MTK.
00060
00061 Options are:
00062 - all: builds the library, the tests, and examples.
00063 - mtklib: builds the library.
```

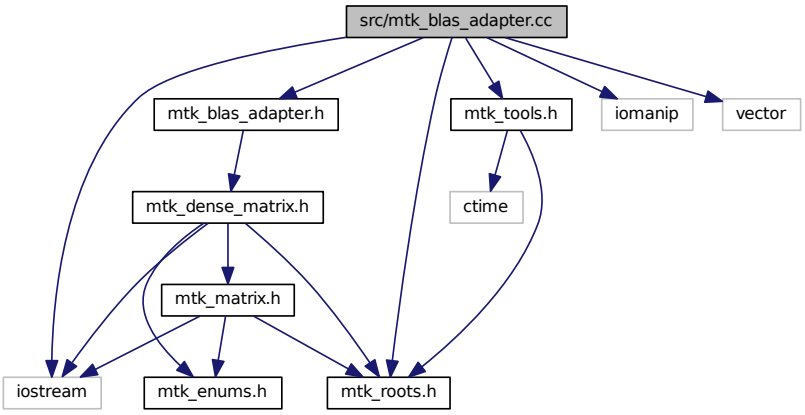
```
00064 - test: builds the test files.
00065 - example: builds the examples.
00066
00067 - testall: runs all the tests.
00068
00069 - gendoc: generates the documentation for the library.
00070
00071 - clean: cleans all the generated files.
00072 - cleanlib: cleans the generated archive and object files.
00073 - cleantest: cleans the generated tests executables.
00074 - cleanexample: cleans the generated examples executables.
00075 -----
00076 ```
00077
00078 ### PART 2. BUILD THE LIBRARY.
00079
00080 ```
00081 $ make
00082 ```
00083
00084 If successful you'll read (before building the tests and examples):
00085
00086 ```
00087 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
00088 ```
00089
00090 ## 4. Contact, Support, and Credits
00091
00092 The MTK is developed by researchers and adjuncts to the
00093 [Computational Science Research Center (CSRC)](http://www.csrc.sdsu.edu/)
00094 at [San Diego State University (SDSU)](http://www.sdsu.edu/).
00095
00096 Developers are members of:
00097
00098 1. Mimetic Numerical Methods Research and Development Group.
00099 2. Computational Geoscience Research and Development Group.
00100 3. Ocean Modeling Research and Development Group.
00101
00102 Currently the developers are:
00103
00104 - **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00105 - Jose E. Castillo, Ph.D. - jcastillo at mail dot sdsu dot edu
00106 - Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
00107 - Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
00108 - Angel Boada.
00109 - Johnny Corbino.
00110 - Raul Vargas-Navarro.
00111
00112 Finally, please feel free to contact me with suggestions or corrections:
00113
00114 **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00115
00116 Thanks and happy coding!
```

## 17.67 src/mtk_blas_adapter.cc File Reference

Adapter class for the BLAS API.

```
#include <iostream>
#include <iomanip>
#include <vector>
#include "mtk_roots.h"
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
```

Include dependency graph for mtk_blas_adapter.cc:




## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

## Functions

- float mtk::snrm2_ (int *n, float *x, int *incx)
- void mtk::saxpy_ (int *n, float *sa, float *sx, int *incx, float *sy, int *incy)
- void mtk::sgemv_ (char *trans, int *m, int *n, float *alpha, float *a, int *lda, float *x, int *incx, float *beta, float *y, int *incy)
- void mtk::sgemm_ (char *transa, char *transb, int *m, int *n, int *k, double *alpha, double *a, int *lda, double *b, aamm int *ldb, double *beta, double *c, int *ldc)

### 17.67.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the BLAS.

The **BLAS (Basic Linear Algebra Subprograms)** are routines that provide standard building blocks for performing basic vector and matrix operations. The Level 1 BLAS perform scalar, vector and vector-vector operations, the Level 2 BLAS perform matrix-vector operations, and the Level 3 BLAS perform matrix-matrix operations.

The BLAS can be installed from links given in the See Also section of this page.

**See also**

http://www.netlib.org/blas/
https://software.intel.com/en-us/non-commercial-software-development

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_blas_adapter.cc.

## 17.68 mtk_blas_adapter.cc

```
00001
00024 /*
00025 Copyright (C) 2015, Computational Science Research Center, San Diego State
00026 University. All rights reserved.
00027
00028 Redistribution and use in source and binary forms, with or without modification,
00029 are permitted provided that the following conditions are met:
00030
00031 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00032 and a copy of the modified files should be reported once modifications are
00033 completed, unless these modifications are made through the project's GitHub
00034 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00035 should be developed and included in any deliverable.
00036
00037 2. Redistributions of source code must be done through direct
00038 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00039
00040 3. Redistributions in binary form must reproduce the above copyright notice,
00041 this list of conditions and the following disclaimer in the documentation and/or
00042 other materials provided with the distribution.
00043
00044 4. Usage of the binary form on proprietary applications shall require explicit
00045 prior written permission from the the copyright holders, and due credit should
00046 be given to the copyright holders.
00047
00048 5. Neither the name of the copyright holder nor the names of its contributors
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00051
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00064 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #include <iostream>
00071 #include <iomanip>
00072
00073 #include <vector>
00074
00075 #include "mtk_roots.h"
00076 #include "mtk_tools.h"
00077 #include "mtk_blas_adapter.h"
00078
00079 namespace mtk {
00080
00081 extern "C" {
00082
00083 #ifdef MTK_PRECISION_DOUBLE
00084
00097 double dnrm2_(int *n, double *x, int *incx);
00098 #else
00099
00112 float snrm2_(int *n, float *x, int *incx);
00113 #endif
00114
```

```
00115 #ifdef MTK_PRECISION_DOUBLE
00116
00135 void daxpy_(int *n, double *da, double *dx, int *incx, double *dy, int *incy);
00136 #else
00137
00156 void saxpy_(int *n, float *sa, float *sx, int *incx, float *sy, int *incy);
00157 #endif
00158
00159 #ifdef MTK_PRECISION_DOUBLE
00160
00188 void dgemv_(char *trans,
00189             int *m,
00190             int *n,
00191             double *alpha,
00192             double *a,
00193             int *lda,
00194             double *x,
00195             int *incx,
00196             double *beta,
00197             double *y,
00198             int *incy);
00199 #else
00200
00228 void sgemv_(char *trans,
00229             int *m,
00230             int *n,
00231             float *alpha,
00232             float *a,
00233             int *lda,
00234             float *x,
00235             int *incx,
00236             float *beta,
00237             float *y,
00238             int *incy);
00239 #endif
00240
00241 #ifdef MTK_PRECISION_DOUBLE
00242
00267 void dgemm_(char *transa,
00268             char* transb,
00269             int *m,
00270             int *n,
00271             int *k,
00272             double *alpha,
00273             double *a,
00274             int *lda,
00275             double *b,
00276             int *ldb,
00277             double *beta,
00278             double *c,
00279             int *ldc);
00280 }
00281 #else
00282
00307 void sgemm_(char *transa,
00308             char* transb,
00309             int *m,
00310             int *n,
00311             int *k,
00312             double *alpha,
00313             double *a,
00314             int *lda,
00315             double *b,aamm
00316             int *ldb,
00317             double *beta,
00318             double *c,
00319             int *ldc);
00320 }
00321 #endif
00322 }
00323
00324 mtk::Real mtk::BLASAdapter::RealNRM2(Real *in, int &in_length) {
00325
00326   #ifdef MTK_PERFORM_PREVENTIONS
00327   mtk::Tools::Prevent(in_length <= 0, __FILE__, __LINE__, __func__);
00328   #endif
00329
00330   int incx{1};  // Increment for the elements of xx. ix >= 0.
00331
00332   #ifdef MTK_PRECISION_DOUBLE
00333   return dnrm2_(&in_length, in, &incx);
```

```
00334   #else
00335   return snrm2_(&in_length, in, &incx);
00336   #endif
00337 }
00338
00339 void mtk::BLASAdapter::RealAXPY(mtk::Real alpha,
00340                                 mtk::Real *xx,
00341                                 mtk::Real *yy,
00342                                 int &in_length) {
00343
00344   #ifdef MTK_PERFORM_PREVENTIONS
00345   mtk::Tools::Prevent(xx == nullptr, __FILE__, __LINE__, __func__);
00346   mtk::Tools::Prevent(yy == nullptr, __FILE__, __LINE__, __func__);
00347   #endif
00348
00349   int incx{1};  // Increment for the elements of xx. ix >= 0.
00350
00351   #ifdef MTK_PRECISION_DOUBLE
00352   daxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00353   #else
00354   saxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00355   #endif
00356 }
00357
00358 mtk::Real mtk::BLASAdapter::RelNorm2Error(
      mtk::Real *computed,
00359                                         mtk::Real *known,
00360                                         int length) {
00361
00362   #ifdef MTK_PERFORM_PREVENTIONS
00363   mtk::Tools::Prevent(computed == nullptr, __FILE__, __LINE__, __func__);
00364   mtk::Tools::Prevent(known == nullptr, __FILE__, __LINE__, __func__);
00365   #endif
00366
00367   mtk::Real norm_2_computed{mtk::BLASAdapter::RealNRM2(known, length)};
00368
00369   mtk::Real alpha{-mtk::kOne};
00370
00371   mtk::BLASAdapter::RealAXPY(alpha, known, computed, length);
00372
00373   mtk::Real norm_2_difference{mtk::BLASAdapter::RealNRM2(computed,
      length)};
00374
00375   return norm_2_difference/norm_2_computed;
00376 }
00377
00378 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00379                                    mtk::DenseMatrix &aa,
00380                                    mtk::Real *xx,
00381                                    mtk::Real &beta,
00382                                    mtk::Real *yy) {
00383
00384   // Make sure input matrices are row-major ordered.
00385
00386   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00387     aa.OrderRowMajor();
00388   }
00389
00390   char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00391
00392   int mm{aa.num_rows()};                  // Rows of aa.
00393   int nn{aa.num_cols()};                  // Columns of aa.
00394   int lda{(aa.matrix_properties()).ld()}; // Leading dimension.
00395   int incx{1};                            // Increment of values in x.
00396   int incy{1};                            // Increment of values in y.
00397
00398   std::swap(mm,nn);
00399   #ifdef MTK_PRECISION_DOUBLE
00400   dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00401          xx, &incx, &beta, yy, &incy);
00402   #else
00403   sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00404         xx, &incx, &beta, yy, &incy);
00405   #endif
00406   std::swap(mm,nn);
00407 }
00408
00409 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
      mtk::DenseMatrix &aa,
00410                                              mtk::DenseMatrix &bb) {
```

```
00411
00412   #ifdef MTK_PERFORM_PREVENTIONS
00413   mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00414                       __FILE__, __LINE__, __func__);
00415   #endif
00416
00418   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00419     aa.OrderRowMajor();
00420   }
00421   if (bb.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00422     bb.OrderRowMajor();
00423   }
00424
00426   char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00427   char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00428
00429   int mm{aa.num_rows()};  // Rows of aa and rows of cc.
00430   int nn{bb.num_cols()};  // Cols of bb and cols of cc.
00431   int kk{aa.num_cols()};  // Cols of aa and rows of bb.
00432
00433   int cc_num_rows{mm};  // Rows of cc.
00434   int cc_num_cols{nn};  // Columns of cc.
00435
00436   int lda{std::max(1,kk)};  // Leading dimension of the aa matrix.
00437   int ldb{std::max(1,nn)};  // Leading dimension of the bb matrix.
00438   int ldc{std::max(1,mm)};  // Leading dimension of the cc matrix.
00439
00440   mtk::Real alpha{mtk::kOne}; // First scalar coefficient.
00441   mtk::Real beta{mtk::kZero}; // Second scalar coefficient.
00442
00443   mtk::DenseMatrix cc_col_maj_ord(cc_num_rows,cc_num_cols); // Output matrix.
00444
00445   cc_col_maj_ord.SetOrdering(mtk::COL_MAJOR);
00446
00448   #ifdef MTK_PRECISION_DOUBLE
00449   dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00450          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00451   #else
00452   sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00453          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00454   #endif
00455
00456   #if MTK_VERBOSE_LEVEL > 12
00457   std::cout << "cc_col_maj_ord =" << std::endl;
00458   std::cout << cc_col_maj_ord << std::endl;
00459   #endif
00460
00461   cc_col_maj_ord.OrderRowMajor();
00462
00463   return cc_col_maj_ord;
00464 }
00465
00466 mtk::DenseMatrix mtk::BLASAdapter::RealDenseSM(
      mtk::Real alpha,
00467                                                mtk::DenseMatrix &aa) {
00468
00469   #ifdef MTK_PERFORM_PREVENTIONS
00470   mtk::Tools::Prevent(aa.num_rows() == 0, __FILE__, __LINE__, __func__);
00471   mtk::Tools::Prevent(aa.num_cols() == 0, __FILE__, __LINE__, __func__);
00472   #endif
00473
00475   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00476     aa.OrderRowMajor();
00477   }
00478
00480   char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00481   char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00482
00483   int mm{aa.num_rows()};  // Rows of aa and rows of cc.
00484   int nn{aa.num_cols()};  // Cols of bb and cols of cc.
00485   int kk{aa.num_cols()};  // Cols of aa and rows of bb.
00486
00487   int lda{std::max(1,kk)};  // Leading dimension of the aa matrix.
00488   int ldb{std::max(1,nn)};  // Leading dimension of the bb matrix.
00489   int ldc{std::max(1,mm)};  // Leading dimension of the cc matrix.
00490
00491   mtk::Real beta{alpha}; // Second scalar coefficient.
00492
```

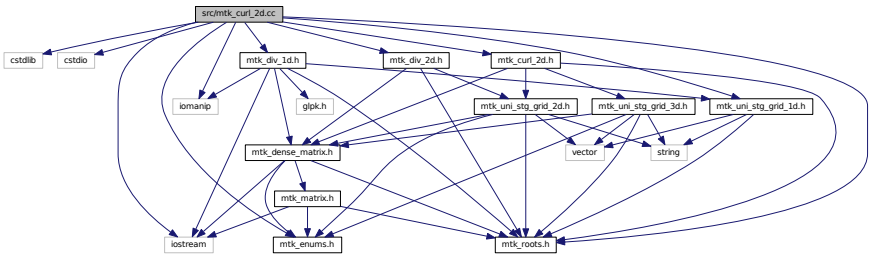
```
00493   alpha = mtk::kZero;
00494
00495   mtk::DenseMatrix alpha_aa(aa); // Output matrix.
00496
00498   #ifdef MTK_PRECISION_DOUBLE
00499   dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00500          aa.data(), &ldb, &beta, alpha_aa.data(), &ldc);
00501   #else
00502   sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00503          aa.data(), &ldb, &beta, alpha_aa.data(), &ldc);
00504   #endif
00505
00506   #if MTK_VERBOSE_LEVEL > 12
00507   std::cout << "alpha_aa =" << std::endl;
00508   std::cout << alpha_aa << std::endl;
00509   #endif
00510
00511   return alpha_aa;
00512 }
```

## 17.69 src/mtk_curl_2d.cc File Reference

Implements the class Curl2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_div_1d.h"
#include "mtk_div_2d.h"
#include "mtk_curl_2d.h"
```

Include dependency graph for mtk_curl_2d.cc:




### 17.69.1 Detailed Description

This class implements a 2D curl matrix operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_curl_2d.cc.

## 17.70 mtk_curl_2d.cc

```
00001
00011 /*
00012 Copyright (C) 2015, Computational Science Research Center, San Diego State
00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
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00032 prior written permission from the the copyright holders, and due credit should
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00034
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00038
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00044
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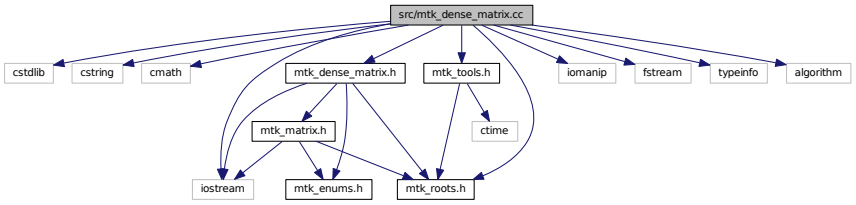
00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_1d.h"
00066 #include "mtk_div_1d.h"
00067 #include "mtk_div_2d.h"
00068 #include "mtk_curl_2d.h"
00069
00070 mtk::UniStgGrid3D mtk::Curl2D::operator*(const
      mtk::UniStgGrid2D &grid) const {
00071
00073
00074   mtk::UniStgGrid3D output;
00075
00076   return output;
00077 }
00078
00079 mtk::Curl2D::Curl2D():
00080   order_accuracy_(),
00081   mimetic_threshold_() {}
00082
00083 mtk::Curl2D::Curl2D(const Curl2D &curl):
00084   order_accuracy_(curl.order_accuracy_),
00085   mimetic_threshold_(curl.mimetic_threshold_) {}
00086
00087 mtk::Curl2D::~Curl2D() {}
```

```
00088
00089 bool mtk::Curl2D::ConstructCurl2D(const
      mtk::UniStgGrid2D &grid,
00090                                  int order_accuracy,
00091                                  mtk::Real mimetic_threshold) {
00092
00093   int num_cells_x = grid.num_cells_x();
00094   int num_cells_y = grid.num_cells_y();
00095
00096   int mx = num_cells_x + 2;  // Dx vertical dimension.
00097   int nx = num_cells_x + 1;  // Dx horizontal dimension.
00098   int my = num_cells_y + 2;  // Dy vertical dimension.
00099   int ny = num_cells_y + 1;  // Dy horizontal dimension.
00100
00101   mtk::Div1D div;
00102
00103   bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00104
00105   #ifdef MTK_PERFORM_PREVENTIONS
00106   if (!info) {
00107     std::cerr << "Mimetic div could not be built." << std::endl;
00108     return info;
00109   }
00110   #endif
00111
00112   auto west = grid.west_bndy();
00113   auto east = grid.east_bndy();
00114   auto south = grid.south_bndy();
00115   auto north = grid.east_bndy();
00116
00117   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00118   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00119
00120   mtk::DenseMatrix dx(div.ReturnAsDenseMatrix(grid_x));
00121   mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00122
00123   bool padded{true};
00124   bool transpose{false};
00125
00126   mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00127   mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00128
00129   mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00130   mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00131
00132   #if MTK_VERBOSE_LEVEL > 2
00133   std::cout << "Dx: " << mx << " by " << nx << std::endl;
00134   std::cout << "Iy : " << num_cells_y<< " by " << ny  << std::endl;
00135   std::cout << "Dy: " << my << " by " << ny << std::endl;
00136   std::cout << "Ix : " << num_cells_x<< " by " << nx  << std::endl;
00137   std::cout << "Curl 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00138     nx*ny <<std::endl;
00139   #endif
00140
00141   mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00142
00143   for (auto ii = 0; ii < mx*my; ii++) {
00144     for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00145       d2d.SetValue(ii, jj, dxy.GetValue(ii,jj));
00146     }
00147     for(auto kk=0; kk<ny*num_cells_x; kk++) {
00148       d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00149     }
00150   }
00151
00152   curl_ = d2d;
00153
00154   return info;
00155 }
00156
00157 mtk::DenseMatrix mtk::Curl2D::ReturnAsDenseMatrix() const {
00158
00159   return curl_;
00160 }
```

## 17.71 src/mtk_dense_matrix.cc File Reference

```
#include <cstdlib>
#include <cstring>
#include <cmath>
#include <iostream>
#include <iomanip>
#include <fstream>
#include <typeinfo>
#include <algorithm>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_tools.h"
```

Include dependency graph for mtk_dense_matrix.cc:




### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::DenseMatrix &in)

## 17.72 mtk_dense_matrix.cc

```
00001
00013 /*
00014 Copyright (C) 2015, Computational Science Research Center, San Diego State
00015 University. All rights reserved.
00016
00017 Redistribution and use in source and binary forms, with or without modification,
00018 are permitted provided that the following conditions are met:
00019
00020 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00021 and a copy of the modified files should be reported once modifications are
00022 completed, unless these modifications are made through the project's GitHub
00023 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00024 should be developed and included in any deliverable.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions in binary form must reproduce the above copyright notice,
00030 this list of conditions and the following disclaimer in the documentation and/or
00031 other materials provided with the distribution.
```

```
00032
00033 4. Usage of the binary form on proprietary applications shall require explicit
00034 prior written permission from the the copyright holders, and due credit should
00035 be given to the copyright holders.
00036
00037 5. Neither the name of the copyright holder nor the names of its contributors
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00049 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00053 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #include <cstdlib>
00060 #include <cstring>
00061 #include <cmath>
00062
00063 #include <iostream>
00064 #include <iomanip>
00065 #include <fstream>
00066
00067 #include <typeinfo>
00068
00069 #include <algorithm>
00070
00071 #include "mtk_roots.h"
00072 #include "mtk_dense_matrix.h"
00073 #include "mtk_tools.h"
00074
00075 namespace mtk {
00076
00077 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00078
00079   int mm{in.matrix_properties_.num_rows()};  // Auxiliary.
00080   int nn{in.matrix_properties_.num_cols()};  // Auxiliary.
00081
00082   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00083     std::swap(mm, nn);
00084   }
00085   for (int ii = 0; ii < mm; ii++) {
00086     int offset{ii*nn};
00087     for (int jj = 0; jj < nn; jj++) {
00088       mtk::Real value = in.data_[offset + jj];
00089       stream << std::setw(9) << value;
00090     }
00091     stream << std::endl;
00092   }
00093   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00094     std::swap(mm, nn);
00095   }
00096   return stream;
00097 }
00098 }
00099
00100 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
      mtk::DenseMatrix &in) {
00101
00102   if(this == &in) {
00103     return *this;
00104   }
00105
00106   matrix_properties_.set_storage(in.
      matrix_properties_.storage());
00107
00108   matrix_properties_.set_ordering(in.
```

```
    matrix_properties_.ordering());
00109
00110   auto aux = in.matrix_properties_.num_rows();
00111   matrix_properties_.set_num_rows(aux);
00112
00113   aux = in.matrix_properties().num_cols();
00114   matrix_properties_.set_num_cols(aux);
00115
00116   aux = in.matrix_properties().num_zero();
00117   matrix_properties_.set_num_zero(aux);
00118
00119   aux = in.matrix_properties().num_null();
00120   matrix_properties_.set_num_null(aux);
00121
00122   auto num_rows = matrix_properties_.num_rows();
00123   auto num_cols = matrix_properties_.num_cols();
00124
00125   delete [] data_;
00126
00127   try {
00128     data_ = new mtk::Real[num_rows*num_cols];
00129   } catch (std::bad_alloc &memory_allocation_exception) {
00130     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00131       std::endl;
00132     std::cerr << memory_allocation_exception.what() << std::endl;
00133   }
00134   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*
    num_cols);
00135
00136   std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00137
00138   return *this;
00139 }
00140
00141 bool mtk::DenseMatrix::operator ==(const
    DenseMatrix &in) {
00142
00143   bool ans{true};
00144
00145   auto mm = in.num_rows();
00146   auto nn = in.num_cols();
00147
00148   if (mm != matrix_properties_.num_rows() ||
00149       nn != matrix_properties_.num_cols()) {
00150     return false;
00151   }
00152
00153   for (int ii = 0; ii < mm && ans; ++ii) {
00154     for (int jj = 0; jj < nn && ans; ++jj) {
00155       ans = ans &&
00156         abs(data_[ii*nn + jj] - in.data()[ii*nn + jj]) <
    mtk::kDefaultTolerance;
00157     }
00158   }
00159   return ans;
00160 }
00161
00162 mtk::DenseMatrix::DenseMatrix(): data_(nullptr) {
00163
00164   matrix_properties_.set_storage(mtk::DENSE);
00165   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00166 }
00167
00168 mtk::DenseMatrix::DenseMatrix(const
    mtk::DenseMatrix &in) {
00169
00170   matrix_properties_.set_storage(in.matrix_properties_.storage());
00171
00172   matrix_properties_.set_ordering(in.matrix_properties_.
    ordering());
00173
00174   auto aux = in.matrix_properties_.num_rows();
00175   matrix_properties_.set_num_rows(aux);
00176
00177   aux = in.matrix_properties().num_cols();
00178   matrix_properties_.set_num_cols(aux);
00179
00180   aux = in.matrix_properties().num_zero();
00181   matrix_properties_.set_num_zero(aux);
00182
00183   aux = in.matrix_properties().num_null();
```

```
00184   matrix_properties_.set_num_null(aux);
00185
00186   auto num_rows = in.matrix_properties_.num_rows();
00187   auto num_cols = in.matrix_properties_.num_cols();
00188
00189   try {
00190     data_ = new mtk::Real[num_rows*num_cols];
00191   } catch (std::bad_alloc &memory_allocation_exception) {
00192     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00193       std::endl;
00194     std::cerr << memory_allocation_exception.what() << std::endl;
00195   }
00196   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00197
00198   std::copy(in.data_,in.data_ + num_rows*num_cols,data_);
00199 }
00200
00201 mtk::DenseMatrix::DenseMatrix(const int &num_rows, const int &num_cols) {
00202
00203   #ifdef MTK_PERFORM_PREVENTIONS
00204   mtk::Tools::Prevent(num_rows < 1, __FILE__, __LINE__, __func__);
00205   mtk::Tools::Prevent(num_cols < 1, __FILE__, __LINE__, __func__);
00206   #endif
00207
00208   matrix_properties_.set_storage(mtk::DENSE);
00209   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00210   matrix_properties_.set_num_rows(num_rows);
00211   matrix_properties_.set_num_cols(num_cols);
00212
00213   try {
00214     data_ = new mtk::Real[num_rows*num_cols];
00215   } catch (std::bad_alloc &memory_allocation_exception) {
00216     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00217       std::endl;
00218     std::cerr << memory_allocation_exception.what() << std::endl;
00219   }
00220   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00221 }
00222
00223 mtk::DenseMatrix::DenseMatrix(const int &rank,
00224                               const bool &padded,
00225                               const bool &transpose) {
00226
00227   #ifdef MTK_PERFORM_PREVENTIONS
00228   mtk::Tools::Prevent(rank < 1, __FILE__, __LINE__, __func__);
00229   #endif
00230
00231   int aux{};  // Used to control the padding.
00232
00233   if (padded) {
00234     aux = 1;
00235   }
00236
00237   matrix_properties_.set_storage(mtk::DENSE);
00238   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00239   matrix_properties_.set_num_rows(aux + rank + aux);
00240   matrix_properties_.set_num_cols(rank);
00241
00242   try {
00243     data_ = new mtk::Real[matrix_properties_.num_values()];
00244   } catch (std::bad_alloc &memory_allocation_exception) {
00245     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00246       std::endl;
00247     std::cerr << memory_allocation_exception.what() << std::endl;
00248   }
00249   memset(data_,
00250          mtk::kZero,
00251          sizeof(data_[0])*(matrix_properties_.num_values()));
00252
00253   for (auto ii =0 ; ii < matrix_properties_.num_rows(); ++ii) {
00254     for (auto jj = 0; jj < matrix_properties_.num_cols(); ++jj) {
00255       data_[ii*matrix_properties_.num_cols() + jj] =
00256         (ii == jj + aux)? mtk::kOne: mtk::kZero;
00257     }
00258   }
00259   if (transpose) {
00260     Transpose();
00261   }
00262 }
00263
00264 mtk::DenseMatrix::DenseMatrix(const mtk::Real *const gen,
```

```
00265                              const int &gen_length,
00266                              const int &pro_length,
00267                              const bool &transpose) {
00268
00269   #ifdef MTK_PERFORM_PREVENTIONS
00270   mtk::Tools::Prevent(gen == nullptr, __FILE__, __LINE__, __func__);
00271   mtk::Tools::Prevent(gen_length < 1, __FILE__, __LINE__, __func__);
00272   mtk::Tools::Prevent(pro_length < 1, __FILE__, __LINE__, __func__);
00273   #endif
00274
00275   matrix_properties_.set_storage(mtk::DENSE);
00276   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00277   if (!transpose) {
00278     matrix_properties_.set_num_rows(gen_length);
00279     matrix_properties_.set_num_cols(pro_length);
00280   } else {
00281     matrix_properties_.set_num_rows(pro_length);
00282     matrix_properties_.set_num_cols(gen_length);
00283   }
00284
00285   int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00286   int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00287
00288   try {
00289     data_ = new mtk::Real[mm*nn];
00290   } catch (std::bad_alloc &memory_allocation_exception) {
00291     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00292       std::endl;
00293     std::cerr << memory_allocation_exception.what() << std::endl;
00294   }
00295   memset(data_, mtk::kZero, sizeof(data_[0])*mm*nn);
00296
00297   if (!transpose) {
00298     for (auto ii = 0; ii < mm; ii++) {
00299       for (auto jj = 0; jj < nn; jj++) {
00300         data_[ii*nn + jj] = pow(gen[ii], (double) jj);
00301       }
00302     }
00303   } else {
00304     for (auto ii = 0; ii < mm; ii++) {
00305       for (auto jj = 0; jj < nn; jj++) {
00306         data_[ii*nn + jj] = pow(gen[jj], (double) ii);
00307       }
00308     }
00309   }
00310 }
00311
00312 mtk::DenseMatrix::~DenseMatrix() {
00313
00314   delete [] data_;
00315   data_ = nullptr;
00316 }
00317
00318 mtk::Matrix mtk::DenseMatrix::matrix_properties() const
     noexcept {
00319
00320   return matrix_properties_;
00321 }
00322
00323 void mtk::DenseMatrix::SetOrdering(
     mtk::MatrixOrdering oo) noexcept {
00324
00325   #ifdef MTK_PERFORM_PREVENTIONS
00326   mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
     mtk::COL_MAJOR),
00327                       __FILE__, __LINE__, __func__);
00328   #endif
00329
00330   matrix_properties_.set_ordering(oo);
00331 }
00332
00333 int mtk::DenseMatrix::num_rows() const noexcept {
00334
00335   return matrix_properties_.num_rows();
00336 }
00337
00338 int mtk::DenseMatrix::num_cols() const noexcept {
00339
00340   return matrix_properties_.num_cols();
00341 }
00342
```

```
00343 mtk::Real* mtk::DenseMatrix::data() const noexcept {
00344
00345   return data_;
00346 }
00347
00348 mtk::Real mtk::DenseMatrix::GetValue(
00349     const int &mm,
00350     const int &nn) const noexcept {
00351
00352   #ifdef MTK_PERFORM_PREVENTIONS
00353   mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00354   mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00355   #endif
00356
00357   return data_[mm*matrix_properties_.num_cols() + nn];
00358 }
00359
00360 void  mtk::DenseMatrix::SetValue(
00361     const int &mm,
00362     const int &nn,
00363     const mtk::Real &val) noexcept {
00364
00365   #ifdef MTK_PERFORM_PREVENTIONS
00366   mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00367   mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00368   #endif
00369
00370   data_[mm*matrix_properties_.num_cols() + nn] = val;
00371 }
00372
00373 void mtk::DenseMatrix::Transpose() {
00374
00376
00377   mtk::Real *data_transposed{}; // Buffer.
00378
00379   int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00380   int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00381
00382   try {
00383     data_transposed = new mtk::Real[mm*nn];
00384   } catch (std::bad_alloc &memory_allocation_exception) {
00385     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00386       std::endl;
00387     std::cerr << memory_allocation_exception.what() << std::endl;
00388   }
00389   memset(data_transposed,
00390          mtk::kZero,
00391          sizeof(data_transposed[0])*mm*nn);
00392
00393   // Assign the values to their transposed position.
00394   for (auto ii = 0; ii < mm; ++ii) {
00395     for (auto jj = 0; jj < nn; ++jj) {
00396       data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00397     }
00398   }
00399
00400   // Swap pointers.
00401   auto tmp = data_; // Temporal holder.
00402   data_ = data_transposed;
00403   delete [] tmp;
00404   tmp = nullptr;
00405
00406   matrix_properties_.set_num_rows(nn);
00407   matrix_properties_.set_num_cols(mm);
00408 }
00409
00410 void mtk::DenseMatrix::OrderRowMajor() {
00411
00412   if (matrix_properties_.ordering() == mtk::COL_MAJOR) {
00413
00415
00416     mtk::Real *data_transposed{}; // Buffer.
00417
00418     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00419     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00420
00421     try {
00422       data_transposed = new mtk::Real[mm*nn];
00423     } catch (std::bad_alloc &memory_allocation_exception) {
00424       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00425         std::endl;
```

```
00426       std::cerr << memory_allocation_exception.what() << std::endl;
00427     }
00428     memset(data_transposed,
00429           mtk::kZero,
00430           sizeof(data_transposed[0])*mm*nn);
00431
00432     // Assign the values to their transposed position.
00433     std::swap(mm, nn);
00434     for (auto ii = 0; ii < mm; ++ii) {
00435       for (auto jj = 0; jj < nn; ++jj) {
00436         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00437       }
00438     }
00439     std::swap(mm, nn);
00440
00441     // Swap pointers.
00442     auto tmp = data_; // Temporal holder.
00443     data_ = data_transposed;
00444     delete [] tmp;
00445     tmp = nullptr;
00446
00447     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00448   }
00449 }
00450
00451 void mtk::DenseMatrix::OrderColMajor() {
00452
00453   if (matrix_properties_.ordering() == ROW_MAJOR) {
00454
00456
00457     mtk::Real *data_transposed{}; // Buffer.
00458
00459     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00460     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00461
00462     try {
00463       data_transposed = new mtk::Real[mm*nn];
00464     } catch (std::bad_alloc &memory_allocation_exception) {
00465       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00466         std::endl;
00467       std::cerr << memory_allocation_exception.what() << std::endl;
00468     }
00469     memset(data_transposed,
00470           mtk::kZero,
00471           sizeof(data_transposed[0])*mm*nn);
00472
00473     // Assign the values to their transposed position.
00474     for (auto ii = 0; ii < mm; ++ii) {
00475       for (auto jj = 0; jj < nn; ++jj) {
00476         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00477       }
00478     }
00479
00480     // Swap pointers.
00481     auto tmp = data_; // Temporal holder.
00482     data_ = data_transposed;
00483     delete [] tmp;
00484     tmp = nullptr;
00485
00486     matrix_properties_.set_ordering(mtk::COL_MAJOR);
00487   }
00488 }
00489
00490 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
      mtk::DenseMatrix &aa,
00491                                         const mtk::DenseMatrix &bb) {
00492
00493   int row_offset{}; // Offset for rows.
00494   int col_offset{}; // Offset for rows.
00495
00496   mtk::Real aa_factor{}; // Used in computation.
00497
00498   // Auxiliary variables:
00499   auto aux1 = aa.matrix_properties_.num_rows()*bb.
      matrix_properties_.num_rows();
00500   auto aux2 = aa.matrix_properties_.num_cols()*bb.
      matrix_properties_.num_cols();
00501
00502   mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00503
00504   int kk_num_cols{output.matrix_properties_.num_cols()}; // Aux.
```

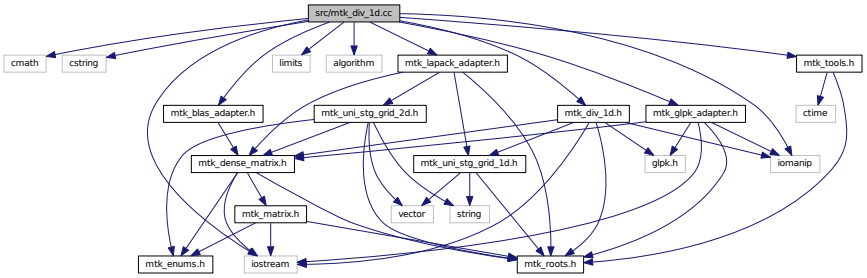
```
00505
00506   auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00507   auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00508   auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00509   auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00510
00511   for (auto ii = 0; ii < mm; ++ii) {
00512     row_offset = ii*pp;
00513     for (auto jj = 0; jj < nn; ++jj) {
00514       col_offset = jj*qq;
00515       aa_factor = aa.data_[ii*nn + jj];
00516       for (auto ll = 0; ll < pp; ++ll) {
00517         for (auto oo = 0; oo < qq; ++oo) {
00518           auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00519           output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00520         }
00521       }
00522     }
00523   }
00524
00525   output.matrix_properties_.set_storage(mtk::DENSE);
00526   output.matrix_properties_.set_ordering(
      mtk::ROW_MAJOR);
00527
00528   return output;
00529 }
00530
00531 bool mtk::DenseMatrix::WriteToFile(const std::string &filename) const {
00532
00533   std::ofstream output_dat_file;  // Output file.
00534
00535   output_dat_file.open(filename);
00536
00537   if (!output_dat_file.is_open()) {
00538     return false;
00539   }
00540
00541   int mm{matrix_properties_.num_rows()};
00542   int nn{matrix_properties_.num_cols()};
00543
00544   for (int ii = 0; ii < mm; ++ii) {
00545     int offset{ii*nn};
00546     for (int jj = 0; jj < nn; ++jj) {
00547       output_dat_file << ii << ' ' << jj << ' ' << data_[offset + jj] <<
00548         std::endl;
00549     }
00550   }
00551
00552   output_dat_file.close();
00553
00554   return true;
00555 }
```

## 17.73 src/mtk_div_1d.cc File Reference

Implements the class Div1D.

```
#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_div_1d.h"
```

Include dependency graph for mtk_div_1d.cc:




## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

## Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::Div1D &in)

### 17.73.1 Detailed Description

This class implements a 1D divergence matrix operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm.

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**Todo** Overload ostream operator as in mtk::Lap1D.

**Todo** Implement creation of ■ w. mtk::BLASAdapter.

Definition in file mtk_div_1d.cc.

## 17.74 mtk_div_1d.cc

```
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00015 /*
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00018
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00023 and a copy of the modified files should be reported once modifications are
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00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
```

```
00027
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00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
00075 #include "mtk_div_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Div1D &in) {
00080
00082
00083   stream << "divergence_[0] = " << std::setw(9) << in.divergence_[0] <<
00084     std::endl;
00085
00087
00088   stream << "divergence_[1:" << in.order_accuracy_ << "] = ";
00089   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00090     stream << std::setw(9) << in.divergence_[ii] << " ";
00091   }
00092   stream << std::endl;
00093
00094   if (in.order_accuracy_ > 2) {
00095
00097
00098     stream << "divergence_[" << in.order_accuracy_ + 1 << ":" <<
00099       2*in.order_accuracy_ << "] = ";
00100     for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00101       stream << std::setw(9) << in.divergence_[ii] << " ";
00102     }
00103     stream << std::endl;
00104
00106
00107     auto offset = (2*in.order_accuracy_ + 1);
00108     int mm{};
00109     for (auto ii = 0; ii < in.dim_null_; ++ii) {
00110       stream << "divergence_[" << offset + mm << ":" <<
```

```
00111         offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00113         auto value = in.divergence_[offset + mm];
00114         stream << std::setw(9) << value << " ";
00115         ++mm;
00116       }
00117       stream << std::endl;
00118     }
00119   }
00120
00121   return stream;
00122 }
00123 }
00124
00125 mtk::Div1D::Div1D():
00126   order_accuracy_(mtk::kDefaultOrderAccuracy),
00127   dim_null_(),
00128   num_bndy_coeffs_(),
00129   divergence_length_(),
00130   minrow_(),
00131   row_(),
00132   coeffs_interior_(),
00133   prem_apps_(),
00134   weights_crs_(),
00135   weights_cbs_(),
00136   mim_bndy_(),
00137   divergence_(),
00138   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00139
00140 mtk::Div1D::Div1D(const Div1D &div):
00141   order_accuracy_(div.order_accuracy_),
00142   dim_null_(div.dim_null_),
00143   num_bndy_coeffs_(div.num_bndy_coeffs_),
00144   divergence_length_(div.divergence_length_),
00145   minrow_(div.minrow_),
00146   row_(div.row_),
00147   coeffs_interior_(div.coeffs_interior_),
00148   prem_apps_(div.prem_apps_),
00149   weights_crs_(div.weights_crs_),
00150   weights_cbs_(div.weights_cbs_),
00151   mim_bndy_(div.mim_bndy_),
00152   divergence_(div.divergence_),
00153   mimetic_threshold_(div.mimetic_threshold_) {}
00154
00155 mtk::Div1D::~Div1D() {
00156
00157   delete[] coeffs_interior_;
00158   coeffs_interior_ = nullptr;
00159
00160   delete[] prem_apps_;
00161   prem_apps_ = nullptr;
00162
00163   delete[] weights_crs_;
00164   weights_crs_ = nullptr;
00165
00166   delete[] weights_cbs_;
00167   weights_cbs_ = nullptr;
00168
00169   delete[] mim_bndy_;
00170   mim_bndy_ = nullptr;
00171
00172   delete[] divergence_;
00173   divergence_ = nullptr;
00174 }
00175
00176 bool mtk::Div1D::ConstructDiv1D(int order_accuracy,
00177                                 mtk::Real mimetic_threshold) {
00178
00179   #ifdef MTK_PERFORM_PREVENTIONS
00180   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00182   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00183                       __FILE__, __LINE__, __func__);
00184
00185   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00186     std::cout << "WARNING: Numerical accuracy is critical." << std::endl;
00187   }
00188
00189   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00190   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00191   #endif
```

```
00192
00193   order_accuracy_ = order_accuracy;
00194   mimetic_threshold_ = mimetic_threshold;
00195
00197
00198   bool abort_construction = ComputeStencilInteriorGrid();
00199
00200   #ifdef MTK_PERFORM_PREVENTIONS
00201   if (!abort_construction) {
00202     std::cerr << "Could NOT complete stage 1." << std::endl;
00203     std::cerr << "Exiting..." << std::endl;
00204     return false;
00205   }
00206   #endif
00207
00208   // At this point, we already have the values for the interior stencil stored
00209   // in the coeffs_interior_ array.
00210
00211   // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00212   // approximation at the boundary, thus it has no weights. For this case, the
00213   // dimension of the null-space of the Vandermonde matrices used to compute the
00214   // approximating coefficients at the boundary is 0. Ergo, we compute this
00215   // number first and then decide if we must compute anything at the boundary.
00216
00217   dim_null_ = order_accuracy_/2 - 1;
00218
00219   if (dim_null_ > 0) {
00220
00221     #ifdef MTK_PRECISION_DOUBLE
00222     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00223     #else
00224     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00225     #endif
00226
00228
00229     // For this we will follow recommendations given in:
00230     //
00231     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00232     //
00233     // We will compute the QR Factorization of the transpose, as in the
00234     // following (MATLAB) pseudo-code:
00235     //
00236     // [Q,R] = qr(V'); % Full QR as defined in
00237     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00238     //
00239     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00240     //
00241     // However, given the nature of the Vandermonde matrices we've just
00242     // computed, they all posses the same null-space. Therefore, we impose the
00243     // convention of computing the null-space of the first Vandermonde matrix
00244     // (west boundary).
00245
00246     abort_construction = ComputeRationalBasisNullSpace();
00247
00248     #ifdef MTK_PERFORM_PREVENTIONS
00249     if (!abort_construction) {
00250       std::cerr << "Could NOT complete stage 2.1." << std::endl;
00251       std::cerr << "Exiting..." << std::endl;
00252       return false;
00253     }
00254     #endif
00255
00257
00258     abort_construction = ComputePreliminaryApproximations();
00259
00260     #ifdef MTK_PERFORM_PREVENTIONS
00261     if (!abort_construction) {
00262       std::cerr << "Could NOT complete stage 2.2." << std::endl;
00263       std::cerr << "Exiting..." << std::endl;
00264       return false;
00265     }
00266     #endif
00267
00269
00270     abort_construction = ComputeWeights();
00271
00272     #ifdef MTK_PERFORM_PREVENTIONS
00273     if (!abort_construction) {
00274       std::cerr << "Could NOT complete stage 2.3." << std::endl;
00275       std::cerr << "Exiting..." << std::endl;
00276       return false;
```

```
00277     }
00278     #endif
00279
00281
00282     abort_construction = ComputeStencilBoundaryGrid();
00283
00284     #ifdef MTK_PERFORM_PREVENTIONS
00285     if (!abort_construction) {
00286       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00287       std::cerr << "Exiting..." << std::endl;
00288       return false;
00289     }
00290     #endif
00291
00292   } // End of: if (dim_null_ > 0);
00293
00295
00296   // Once we have the following three collections of data:
00297   //   (a) the coefficients for the interior,
00298   //   (b) the coefficients for the boundary (if it applies),
00299   //   (c) and the weights (if it applies),
00300   // we will store everything in the output array:
00301
00302   abort_construction = AssembleOperator();
00303
00304   #ifdef MTK_PERFORM_PREVENTIONS
00305   if (!abort_construction) {
00306     std::cerr << "Could NOT complete stage 3." << std::endl;
00307     std::cerr << "Exiting..." << std::endl;
00308     return false;
00309   }
00310   #endif
00311
00312   return true;
00313 }
00314
00315 int mtk::Div1D::num_bndy_coeffs() const {
00316
00317   return num_bndy_coeffs_;
00318 }
00319
00320 mtk::Real *mtk::Div1D::coeffs_interior() const {
00321
00322   return coeffs_interior_;
00323 }
00324
00325 mtk::Real *mtk::Div1D::weights_crs() const {
00326
00327   return weights_crs_;
00328 }
00329
00330 mtk::Real *mtk::Div1D::weights_cbs() const {
00331
00332   return weights_cbs_;
00333 }
00334
00335 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00336
00337   mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00338
00339   auto counter = 0;
00340   for (auto ii = 0; ii < dim_null_; ++ii) {
00341     for(auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00342       xx.SetValue(ii,jj, divergence_[2*order_accuracy_ + 1 + counter]);
00343       counter++;
00344     }
00345   }
00346
00347   return xx;
00348 }
00349
00350 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(
00351   const UniStgGrid1D &grid) const {
00352
00353   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00354
00355   #ifdef MTK_PERFORM_PREVENTIONS
00356   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00357   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00358   #endif
00359
```

```
00360   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00361
00362   int dd_num_rows = nn + 2;
00363   int dd_num_cols = nn + 1;
00364   int elements_per_row = num_bndy_coeffs_;
00365   int num_extra_rows = dim_null_;
00366
00367   // Output matrix featuring sizes for divergence operators.
00368   mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00369
00371
00372   auto ee_index = 0;
00373   for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00374     auto cc = 0;
00375     for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00376       if( cc >= elements_per_row) {
00377         out.SetValue(ii, jj, mtk::kZero);
00378       } else {
00379         out.SetValue(ii,jj, mim_bndy_[ee_index++]*inv_delta_x);
00380         cc++;
00381       }
00382     }
00383   }
00384
00386
00387   for (auto ii = num_extra_rows + 1;
00388        ii < dd_num_rows - num_extra_rows - 1; ii++) {
00389     auto jj = ii - num_extra_rows - 1;
00390     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00391       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00392     }
00393   }
00394
00396
00397   ee_index = 0;
00398   for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--)
00399 {
00400     auto cc = 0;
00401     for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00402       if( cc >= elements_per_row) {
00403         out.SetValue(ii,jj,0.0);
00404       } else {
00405         out.SetValue(ii,jj,-mim_bndy_[ee_index++]*inv_delta_x);
00406         cc++;
00407       }
00408      }
00409   }
00410
00411   return out;
00412 }
00413
00414 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00415
00417
00418   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00419
00420   try {
00421     pp = new mtk::Real[order_accuracy_];
00422   } catch (std::bad_alloc &memory_allocation_exception) {
00423     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00424       std::endl;
00425     std::cerr << memory_allocation_exception.what() << std::endl;
00426   }
00427   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00428
00429   #ifdef MTK_PRECISION_DOUBLE
00430   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00431   #else
00432   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00433   #endif
00434
00435   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00436     pp[ii] = pp[ii - 1] + mtk::kOne;
00437   }
00438
00439   #if MTK_VERBOSE_LEVEL > 3
00440   std::cout << "pp =" << std::endl;
00441   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00442     std::cout << std::setw(12) << pp[ii];
00443   }
00444   std::cout << std::endl << std::endl;
```

```
00445   #endif
00446
00448
00449   bool transpose{false};
00450
00451   mtk::DenseMatrix vander_matrix(pp,
00452                                  order_accuracy_,
00453                                  order_accuracy_,
00454                                  transpose);
00455
00456   #if MTK_VERBOSE_LEVEL > 4
00457   std::cout << "vander_matrix = " << std::endl;
00458   std::cout << vander_matrix << std::endl;
00459   #endif
00460
00462
00463   try {
00464     coeffs_interior_ = new mtk::Real[order_accuracy_];
00465   } catch (std::bad_alloc &memory_allocation_exception) {
00466     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00467       std::endl;
00468     std::cerr << memory_allocation_exception.what() << std::endl;
00469   }
00470   memset(coeffs_interior_,
00471          mtk::kZero,
00472          sizeof(coeffs_interior_[0])*order_accuracy_);
00473
00474   coeffs_interior_[1] = mtk::kOne;
00475
00476   #if MTK_VERBOSE_LEVEL > 3
00477   std::cout << "oo =" << std::endl;
00478   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00479     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00480   }
00481   std::cout << std::endl;
00482   #endif
00483
00485
00486   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00487                                                 coeffs_interior_)};
00488
00489   #ifdef MTK_PERFORM_PREVENTIONS
00490   if (!info) {
00491     std::cout << "System solved! Interior stencil attained!" << std::endl;
00492     std::cout << std::endl;
00493   }
00494   else {
00495     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00496     std::cerr << "Exiting..." << std::endl;
00497     return false;
00498   }
00499   #endif
00500
00501   #if MTK_VERBOSE_LEVEL > 3
00502   std::cout << "coeffs_interior_ =" << std::endl;
00503   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00504     std::cout << std::setw(12) << coeffs_interior_[ii];
00505   }
00506   std::cout << std::endl << std::endl;
00507   #endif
00508
00509   delete [] pp;
00510   pp = nullptr;
00511
00512   return true;
00513 }
00514
00515 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00516
00517   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00518
00520
00521   try {
00522     gg = new mtk::Real[num_bndy_coeffs_];
00523   } catch (std::bad_alloc &memory_allocation_exception) {
00524     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00525       std::endl;
00526     std::cerr << memory_allocation_exception.what() << std::endl;
00527   }
00528   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00529
```

```
00530   #ifdef MTK_PRECISION_DOUBLE
00531   gg[0] = -1.0/2.0;
00532   #else
00533   gg[0] = -1.0f/2.0f;
00534   #endif
00535   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00536     gg[ii] = gg[ii - 1] + mtk::kOne;
00537   }
00538
00539   #if MTK_VERBOSE_LEVEL > 3
00540   std::cout << "gg =" << std::endl;
00541   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00542     std::cout << std::setw(12) << gg[ii];
00543   }
00544   std::cout << std::endl << std::endl;
00545   #endif
00546
00548
00549   bool tran{true}; // Should I transpose the Vandermonde matrix.
00550
00551   mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00552
00553   #if MTK_VERBOSE_LEVEL > 4
00554   std::cout << "vv_west_t =" << std::endl;
00555   std::cout << vv_west_t << std::endl;
00556   #endif
00557
00559
00560   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
    (vv_west_t));
00561
00562   #if MTK_VERBOSE_LEVEL > 4
00563   std::cout << "QQ^T = " << std::endl;
00564   std::cout << qq_t << std::endl;
00565   #endif
00566
00568
00569   int KK_num_rows_{num_bndy_coeffs_};
00570   int KK_num_cols_{dim_null_};
00571
00572   mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00573
00574   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00575     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00576       KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00577           qq_t.data()[ii*num_bndy_coeffs_ + jj];
00578     }
00579   }
00580
00581   #if MTK_VERBOSE_LEVEL > 2
00582   std::cout << "KK =" << std::endl;
00583   std::cout << KK << std::endl;
00584   std::cout << "KK.num_rows() = " << KK.num_rows() << std::endl;
00585   std::cout << "KK.num_cols() = " << KK.num_cols() << std::endl;
00586   std::cout << std::endl;
00587   #endif
00588
00590
00591   // Scale thus requesting that the last entries of the attained basis for the
00592   // null-space, adopt the pattern we require.
00593   // Essentially we will implement the following MATLAB pseudo-code:
00594   //  scalers = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00595   //  SK = KK*scalers
00596   // where SK is the scaled null-space.
00597
00598   // In this point, we almost have all the data we need correctly allocated
00599   // in memory. We will create the matrix II_, and elements we wish to scale in
00600   // the KK array. Using the concept of the leading dimension, we could just
00601   // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00602   // GET how does it work. So I will just create a matrix with the content of
00603   // this array that we need, solve for the scalers and then scale the
00604   // whole KK:
00605
00606   // We will then create memory for that sub-matrix of KK (SUBK).
00607
00608   mtk::DenseMatrix SUBK(dim_null_,dim_null_);
00609
00610   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00611     for (auto jj = 0; jj < dim_null_; ++jj) {
00612       SUBK.data()[(ii - (num_bndy_coeffs_ - dim_null_))*dim_null_ + jj] =
00613           KK.data()[ii*dim_null_ + jj];
```

```
00614     }
00615   }
00616
00617   #if MTK_VERBOSE_LEVEL > 4
00618   std::cout << "SUBK =" << std::endl;
00619   std::cout << SUBK << std::endl;
00620   #endif
00621
00622   SUBK.Transpose();
00623
00624   #if MTK_VERBOSE_LEVEL > 4
00625   std::cout << "SUBK^T =" << std::endl;
00626   std::cout << SUBK << std::endl;
00627   #endif
00628
00629   bool padded{false};
00630   tran = false;
00631
00632   mtk::DenseMatrix II(dim_null_, padded, tran);
00633
00634   #if MTK_VERBOSE_LEVEL > 4
00635   std::cout << "II =" << std::endl;
00636   std::cout << II << std::endl;
00637   #endif
00638
00639   // Solve the system to compute the scalers.
00640   // An example of the system to solve, for k = 8, is:
00641   //
00642   // SUBK*scalers = II_ or
00643   //
00644   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00645   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00646   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00647   //
00648   // Notice this is a nrhs = 3 system.
00649   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00650   // will be stored in the created identity matrix.
00651   // Let us first transpose SUBK (because of LAPACK):
00652
00653   int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00654
00655   #ifdef MTK_PERFORM_PREVENTIONS
00656   if (!info) {
00657     std::cout << "System successfully solved!" <<
00658       std::endl;
00659   } else {
00660     std::cerr << "Something went wrong solving system! info = " << info <<
00661       std::endl;
00662     std::cerr << "Exiting..." << std::endl;
00663     return false;
00664   }
00665   std::cout << std::endl;
00666   #endif
00667
00668   #if MTK_VERBOSE_LEVEL > 4
00669   std::cout << "Computed scalers:" << std::endl;
00670   std::cout << II << std::endl;
00671   #endif
00672
00673   // Multiply the two matrices to attain a scaled basis for null-space.
00674
00675   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00676
00677   #if MTK_VERBOSE_LEVEL > 4
00678   std::cout << "Rational basis for the null-space:" << std::endl;
00679   std::cout << rat_basis_null_space_ << std::endl;
00680   #endif
00681
00682   // At this point, we have a rational basis for the null-space, with the
00683   // pattern we need! :)
00684
00685   delete [] gg;
00686   gg = nullptr;
00687
00688   return true;
00689 }
00690
00691 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00692
00694
00695   mtk::Real *gg{}; // Generator vector for the first approximation.
```

```
00696
00697   try {
00698     gg = new mtk::Real[num_bndy_coeffs_];
00699   } catch (std::bad_alloc &memory_allocation_exception) {
00700     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00701 std::endl;
00702     std::cerr << memory_allocation_exception.what() << std::endl;
00703   }
00704   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00705
00706   #ifdef MTK_PRECISION_DOUBLE
00707   gg[0] = -1.0/2.0;
00708   #else
00709   gg[0] = -1.0f/2.0f;
00710   #endif
00711   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00712     gg[ii] = gg[ii - 1] + mtk::kOne;
00713   }
00714
00715   #if MTK_VERBOSE_LEVEL > 3
00716   std::cout << "gg0 =" << std::endl;
00717   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00718     std::cout << std::setw(12) << gg[ii];
00719   }
00720   std::cout << std::endl << std::endl;
00721   #endif
00722
00723   // Allocate 2D array to store the collection of preliminary approximations.
00724   try {
00725     prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
00726   } catch (std::bad_alloc &memory_allocation_exception) {
00727     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00728       std::endl;
00729     std::cerr << memory_allocation_exception.what() << std::endl;
00730   }
00731   memset(prem_apps_,
00732          mtk::kZero,
00733          sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00734
00736
00737   for (auto ll = 0; ll < dim_null_; ++ll) {
00738
00739     // Re-check new generator vector for every iteration except for the first.
00740     #if MTK_VERBOSE_LEVEL > 3
00741     if (ll > 0) {
00742       std::cout << "gg" << ll << " =" << std::endl;
00743       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00744         std::cout << std::setw(12) << gg[ii];
00745       }
00746       std::cout << std::endl << std::endl;
00747     }
00748     #endif
00749
00751
00752     bool transpose{false};
00753
00754     mtk::DenseMatrix AA_(gg,
00755                          num_bndy_coeffs_, order_accuracy_ + 1,
00756                          transpose);
00757
00758     #if MTK_VERBOSE_LEVEL > 4
00759     std::cout << "AA_" << ll << " =" << std::endl;
00760     std::cout << AA_ << std::endl;
00761     #endif
00762
00764
00765     mtk::Real *ob{};
00766
00767     auto ob_ld = num_bndy_coeffs_;
00768
00769     try {
00770       ob = new mtk::Real[ob_ld];
00771     } catch (std::bad_alloc &memory_allocation_exception) {
00772       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00773         std::endl;
00774       std::cerr << memory_allocation_exception.what() << std::endl;
00775     }
00776     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00777
00778     ob[1] = mtk::kOne;
00779
```

```
00780     #if MTK_VERBOSE_LEVEL > 4
00781     std::cout << "ob = " << std::endl << std::endl;
00782     for (auto ii = 0; ii < ob_ld; ++ii) {
00783       std::cout << std::setw(12) << ob[ii] << std::endl;
00784     }
00785     std::cout << std::endl;
00786     #endif
00787
00789
00790     // However, this is an under-determined system of equations. So we can not
00791     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00792     // our LAPACKAdapter class.
00793
00794     int info_{
00795       mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
      ob, ob_ld)};
00796
00797     #ifdef MTK_PERFORM_PREVENTIONS
00798     if (!info_) {
00799       std::cout << "System successfully solved!" << std::endl << std::endl;
00800     } else {
00801       std::cerr << "Error solving system! info = " << info_ << std::endl;
00802     }
00803     #endif
00804
00805     #if MTK_VERBOSE_LEVEL > 3
00806     std::cout << "ob =" << std::endl;
00807     for (auto ii = 0; ii < ob_ld; ++ii) {
00808       std::cout << std::setw(12) << ob[ii] << std::endl;
00809     }
00810     std::cout << std::endl;
00811     #endif
00812
00814
00815     // This implies a DAXPY operation. However, we must construct the arguments
00816     // for this operation.
00817
00819     // Save them into the ob_bottom array:
00820
00821     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00822
00823     try {
00824       ob_bottom = new mtk::Real[dim_null_];
00825     } catch (std::bad_alloc &memory_allocation_exception) {
00826       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00827         std::endl;
00828       std::cerr << memory_allocation_exception.what() << std::endl;
00829     }
00830     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00831
00832     for (auto ii = 0; ii < dim_null_; ++ii) {
00833       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00834     }
00835
00836     #if MTK_VERBOSE_LEVEL > 3
00837     std::cout << "ob_bottom =" << std::endl;
00838     for (auto ii = 0; ii < dim_null_; ++ii) {
00839       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00840     }
00841     std::cout << std::endl;
00842     #endif
00843
00845
00846     // We must computed an scaled ob, sob, using the scaled null-space in
00847     // rat_basis_null_space_.
00848     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00849     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00850     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00851
00852     #if MTK_VERBOSE_LEVEL > 3
00853     std::cout << "Rational basis for the null-space:" << std::endl;
00854     std::cout << rat_basis_null_space_ << std::endl;
00855     #endif
00856
00857     mtk::Real alpha{-mtk::kOne};
00858     mtk::Real beta{mtk::kOne};
00859
00860     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00861                                   ob_bottom, beta, ob);
00862
00863     #if MTK_VERBOSE_LEVEL > 3
```

```
00864     std::cout << "scaled ob:" << std::endl;
00865     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00866       std::cout << std::setw(12) << ob[ii] << std::endl;
00867     }
00868     std::cout << std::endl;
00869     #endif
00870
00871     // We save the recently scaled solution, into an array containing these.
00872     // We can NOT start building the pi matrix, simply because I want that part
00873     // to be separated since its construction depends on the algorithm we want
00874     // to implement.
00875
00876     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00877       prem_apps_[ii*dim_null_ + ll] = ob[ii];
00878     }
00879
00880     // After the first iteration, simply shift the entries of the last
00881     // generator vector used:
00882     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00883       gg[ii]--;
00884     }
00885
00886     // Garbage collection for this loop:
00887     delete[] ob;
00888     ob = nullptr;
00889
00890     delete[] ob_bottom;
00891     ob_bottom = nullptr;
00892   } // End of: for (ll = 0; ll < dim_null; ll++);
00893
00894   #if MTK_VERBOSE_LEVEL > 4
00895   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00896   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00897     for (auto jj = 0; jj < dim_null_; ++jj) {
00898       std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00899     }
00900     std::cout << std::endl;
00901   }
00902   std::cout << std::endl;
00903   #endif
00904
00905   delete[] gg;
00906   gg = nullptr;
00907
00908   return true;
00909 }
00910
00911 bool mtk::Div1D::ComputeWeights(void) {
00912
00913   // Matrix to copmpute the weights as in the CRSA.
00914   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00915
00917
00918   // Assemble the pi matrix using:
00919   // 1. The collection of scaled preliminary approximations.
00920   // 2. The collection of coefficients approximating at the interior.
00921   // 3. The scaled basis for the null-space.
00922
00923   // 1.1. Process array of scaled preliminary approximations.
00924
00925   // These are queued in scaled_solutions. Each one of these, will be a column
00926   // of the pi matrix:
00927   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00928     for (auto jj = 0; jj < dim_null_; ++jj) {
00929       pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00930         prem_apps_[ii*dim_null_ + jj];
00931     }
00932   }
00933
00934   // 1.2. Add columns from known stencil approximating at the interior.
00935
00936   // However, these must be padded by zeros, according to their position in the
00937   // final pi matrix:
00938   auto mm = 0;
00939   for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00940     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00941       pi.data()[(ii + mm)*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00942         coeffs_interior_[ii];
00943     }
00944     ++mm;
00945   }
```

```
00946
00947   rat_basis_null_space_.OrderColMajor();
00948
00949   #if MTK_VERBOSE_LEVEL > 4
00950   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00951   std::cout << rat_basis_null_space_ << std::endl;
00952   #endif
00953
00954   // 1.3. Add final set of columns: rational basis for null-space.
00955   for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
00956        jj < num_bndy_coeffs_ - 1;
00957        ++jj) {
00958     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00959       auto og =
00960         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00961       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00962       pi.data()[de] = rat_basis_null_space_.data()[og];
00963     }
00964   }
00965
00966   #if MTK_VERBOSE_LEVEL > 3
00967   std::cout << "coeffs_interior_ =" << std::endl;
00968   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00969     std::cout << std::setw(12) << coeffs_interior_[ii];
00970   }
00971   std::cout << std::endl << std::endl;
00972   #endif
00973
00974   #if MTK_VERBOSE_LEVEL > 4
00975   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00976   std::cout << pi << std::endl;
00977   #endif
00978
00980
00981   // This imposes the mimetic condition.
00982
00983   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
00984
00985   try {
00986     hh = new mtk::Real[num_bndy_coeffs_];
00987   } catch (std::bad_alloc &memory_allocation_exception) {
00988     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00989       std::endl;
00990     std::cerr << memory_allocation_exception.what() << std::endl;
00991   }
00992   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00993
00994   hh[0] = -mtk::kOne;
00995   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00996     auto aux_xx = mtk::kZero;
00997     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00998       aux_xx += coeffs_interior_[jj];
00999     }
01000     hh[ii] = -mtk::kOne*aux_xx;
01001   }
01002
01004
01005   // That is, we construct a system, to solve for the weights.
01006
01007   // Once again we face the challenge of solving with LAPACK. However, for the
01008   // CRSA, this matrix PI is over-determined, since it has more rows than
01009   // unknowns. However, according to the theory, the solution to this system is
01010   // unique. We will use dgels_.
01011
01012   try {
01013     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01014   } catch (std::bad_alloc &memory_allocation_exception) {
01015     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01016       std::endl;
01017     std::cerr << memory_allocation_exception.what() << std::endl;
01018   }
01019   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01020
01021   int weights_ld{pi.num_cols() + 1};
01022
01023   // Preserve hh.
01024   std::copy(hh, hh + weights_ld, weights_cbs_);
01025
01026   pi.Transpose();
01027
01028   int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
```

```
      pi,
01029                                                          weights_cbs_,
01030                                                          weights_ld)};
01031
01032   #ifdef MTK_PERFORM_PREVENTIONS
01033   if (!info) {
01034     std::cout << "System successfully solved!" << std::endl << std::endl;
01035   } else {
01036     std::cerr << "Error solving system! info = " << info << std::endl;
01037   }
01038   #endif
01039
01040   #if MTK_VERBOSE_LEVEL > 3
01041   std::cout << "hh =" << std::endl;
01042   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01043     std::cout << std::setw(11) << hh[ii] << std::endl;
01044   }
01045   std::cout << std::endl;
01046   #endif
01047
01048   // Preserve the original weights for research.
01049
01050   try {
01051     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01052   } catch (std::bad_alloc &memory_allocation_exception) {
01053     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01054       std::endl;
01055     std::cerr << memory_allocation_exception.what() << std::endl;
01056   }
01057   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01058
01059   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01060
01061   #if MTK_VERBOSE_LEVEL > 3
01062   std::cout << "weights_CRSA + lambda =" << std::endl;
01063   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01064     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01065   }
01066   std::cout << std::endl;
01067   #endif
01068
01070
01071   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01072
01073     int minrow_{std::numeric_limits<int>::infinity()};
01074
01075     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01076     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01077
01079
01080     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01081
01082     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01083       for (auto jj = 0; jj < dim_null_; ++jj) {
01084         phi.data()[ii*(order_accuracy_) + jj] = prem_apps_[ii*dim_null_ + jj];
01085       }
01086     }
01087
01088     int aux{};  // Auxiliary variable.
01089     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01090       for (auto ii = 0; ii < order_accuracy_; ++ii) {
01091         phi.data()[(ii + aux)*order_accuracy_ + jj] = coeffs_interior_[ii];
01092       }
01093       ++aux;
01094     }
01095
01096     for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01097       for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01098         phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01099       }
01100     }
01101
01102     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01103       for (auto ii = 0; ii < dim_null_; ++ii) {
01104         phi.data()[(ii + order_accuracy_ - dim_null_ + jj*order_accuracy_)] =
01105           -prem_apps_[(dim_null_ - ii - 1 + jj*dim_null_)];
01106       }
01107     }
01108
01109     for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
```

```
01110       for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01111         auto swap = phi.data()[ii*order_accuracy_+jj];
01112         phi.data()[ii*order_accuracy_ + jj] =
01113           phi.data()[(order_accuracy_-ii)*order_accuracy_+jj];
01114         phi.data()[(order_accuracy_-ii)*order_accuracy_+jj] = swap;
01115       }
01116     }
01117
01118     #if MTK_VERBOSE_LEVEL > 4
01119     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01120     std::cout << phi << std::endl;
01121     #endif
01122
01124
01125     mtk::Real *lamed{};  // Used to build big lambda.
01126
01127     try {
01128       lamed = new mtk::Real[dim_null_];
01129     } catch (std::bad_alloc &memory_allocation_exception) {
01130       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01131         std::endl;
01132       std::cerr << memory_allocation_exception.what() << std::endl;
01133     }
01134     memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01135
01136     for (auto ii = 0; ii < dim_null_; ++ii) {
01137       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01138     }
01139
01140     #if MTK_VERBOSE_LEVEL > 3
01141     std::cout << "lamed =" << std::endl;
01142     for (auto ii = 0; ii < dim_null_; ++ii) {
01143       std::cout << std::setw(12) << lamed[ii] << std::endl;
01144     }
01145     std::cout << std::endl;
01146     #endif
01147
01148     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01149       mtk::Real temp = mtk::kZero;
01150       for(auto jj = 0; jj < dim_null_; ++jj) {
01151         temp = temp +
01152           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01153       }
01154       hh[ii] = hh[ii] - temp;
01155     }
01156
01157     #if MTK_VERBOSE_LEVEL > 3
01158     std::cout << "big_lambda =" << std::endl;
01159     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01160       std::cout << std::setw(12) << hh[ii] << std::endl;
01161     }
01162     std::cout << std::endl;
01163     #endif
01164
01165     int copy_result{};
01166
01167     mtk::Real normerr_; // Norm of the error for the solution on each row.
01168
01170
01171     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01172       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01173                                                           order_accuracy_ + 1,
01174                                                           order_accuracy_,
01175                                                           order_accuracy_,
01176                                                           hh,
01177                                                           weights_cbs_,
01178                                                           row_,
01179                                                           mimetic_threshold_,
01180                                                           copy_result);
01181       mtk::Real aux{normerr_/norm_};
01182
01183       #if MTK_VERBOSE_LEVEL > 2
01184       std::cout << "Relative norm: " << aux << " " << std::endl;
01185       std::cout << std::endl;
01186       #endif
01187
01188       if (aux < minnorm_) {
01189         minnorm_ = aux;
01190         minrow_= row_;
01191       }
```

```
01192     }
01193
01194     #if MTK_VERBOSE_LEVEL > 3
01195     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01196       std::endl;
01197     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01198       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01199     }
01200     std::cout << std::endl;
01201     #endif
01202
01204
01205     // After we know which row yields the smallest relative norm that row is
01206     // chosen to be the objective function and the result of the optimizer is
01207     // chosen to be the new weights_.
01208
01209     #if MTK_VERBOSE_LEVEL > 2
01210     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01211       minrow_ + 1 << std::endl;
01212     std::cout << std::endl;
01213     #endif
01214
01215     copy_result = 1;
01216     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01217                                                         order_accuracy_ + 1,
01218                                                         order_accuracy_,
01219                                                         order_accuracy_,
01220                                                         hh,
01221                                                         weights_cbs_,
01222                                                         minrow_,
01223                                                         mimetic_threshold_,
01224                                                         copy_result);
01225     mtk::Real aux_{normerr_/norm_};
01226     #if MTK_VERBOSE_LEVEL > 2
01227     std::cout << "Relative norm: " << aux_ << std::endl;
01228     std::cout << std::endl;
01229     #endif
01230
01231     delete [] lamed;
01232     lamed = nullptr;
01233   }
01234
01235   delete [] hh;
01236   hh = nullptr;
01237
01238   return true;
01239 }
01240
01241 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01242
01243   #if MTK_VERBOSE_LEVEL > 3
01244   std::cout << "weights_CBSA + lambda =" << std::endl;
01245   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01246     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01247   }
01248   std::cout << std::endl;
01249   #endif
01250
01252
01253   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01254
01255   try {
01256     lambda = new mtk::Real[dim_null_];
01257   } catch (std::bad_alloc &memory_allocation_exception) {
01258     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01259       std::endl;
01260     std::cerr << memory_allocation_exception.what() << std::endl;
01261   }
01262   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01263
01264   for (auto ii = 0; ii < dim_null_; ++ii) {
01265     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01266   }
01267
01268   #if MTK_VERBOSE_LEVEL > 3
01269   std::cout << "lambda =" << std::endl;
01270   for (auto ii = 0; ii < dim_null_; ++ii) {
01271     std::cout << std::setw(12) << lambda[ii] << std::endl;
01272   }
01273   std::cout << std::endl;
```

```
01274   #endif
01275
01277
01278   mtk::Real *alpha{}; // Collection of alpha values.
01279
01280   try {
01281     alpha = new mtk::Real[dim_null_];
01282   } catch (std::bad_alloc &memory_allocation_exception) {
01283     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01284       std::endl;
01285     std::cerr << memory_allocation_exception.what() << std::endl;
01286   }
01287   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01288
01289   for (auto ii = 0; ii < dim_null_; ++ii) {
01290     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01291   }
01292
01293   #if MTK_VERBOSE_LEVEL > 3
01294   std::cout << "alpha =" << std::endl;
01295   for (auto ii = 0; ii < dim_null_; ++ii) {
01296     std::cout << std::setw(12) << alpha[ii] << std::endl;
01297   }
01298   std::cout << std::endl;
01299   #endif
01300
01302
01303   try {
01304     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01305   } catch (std::bad_alloc &memory_allocation_exception) {
01306     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01307       std::endl;
01308     std::cerr << memory_allocation_exception.what() << std::endl;
01309   }
01310   memset(mim_bndy_,
01311          mtk::kZero,
01312          sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01313
01314   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01315     for (auto jj = 0; jj < dim_null_; ++jj) {
01316       mim_bndy_[ii*dim_null_ + jj] =
01317         prem_apps_[ii*dim_null_ + jj] +
01318         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01319     }
01320   }
01321
01322   #if MTK_VERBOSE_LEVEL > 3
01323   std::cout << "Collection of mimetic approximations:" << std::endl;
01324   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01325     for (auto jj = 0; jj < dim_null_; ++jj) {
01326       std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01327     }
01328     std::cout << std::endl;
01329   }
01330   std::cout << std::endl;
01331   #endif
01332
01333   delete[] lambda;
01334   lambda = nullptr;
01335
01336   delete[] alpha;
01337   alpha = nullptr;
01338
01339   return true;
01340 }
01341
01342 bool mtk::Div1D::AssembleOperator(void) {
01343
01344   // The output array will have this form:
01345   // 1. The first entry of the array will contain used order order_accuracy_.
01346   // 2. The second entry of the array will contain the collection of
01347   // approximating coefficients for the interior of the grid.
01348   // 3. IF order_accuracy_ > 2, then the third entry will contain a collection
01349   // of weights.
01350   // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the
01351   // collections of approximating coefficients for the west boundary of the
01352   // grid.
01353
01354   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01355     divergence_length_ =
01356       1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
```

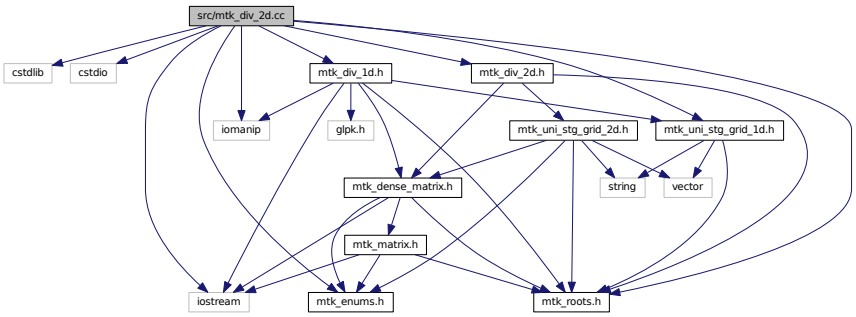
```
01357   } else {
01358     divergence_length_ = 1 + order_accuracy_;
01359   }
01360
01361   #if MTK_VERBOSE_LEVEL > 2
01362   std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01363   #endif
01364
01365   try {
01366     divergence_ = new double[divergence_length_];
01367   } catch (std::bad_alloc &memory_allocation_exception) {
01368     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01369       std::endl;
01370     std::cerr << memory_allocation_exception.what() << std::endl;
01371   }
01372   memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01373
01375
01376   divergence_[0] = order_accuracy_;
01377
01379
01380   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01381   divergence_[ii + 1] = coeffs_interior_[ii];
01382   }
01383
01385
01386   if (order_accuracy_ > 2) {
01387     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01388       divergence_[(1 + order_accuracy_) + ii] = weights_cbs_[ii];
01389     }
01390   }
01391
01394
01395   if (order_accuracy_ > 2) {
01396     auto offset = (2*order_accuracy_ + 1);
01397     int mm{};
01398     for (auto ii = 0; ii < dim_null_; ++ii) {
01399       for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01400         divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01401         ++mm;
01402       }
01403     }
01404   }
01405
01406   #if MTK_VERBOSE_LEVEL > 1
01407   std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01408   std::cout << std::endl;
01409   #endif
01410
01411   return true;
01412 }
```

## 17.75 src/mtk_div_2d.cc File Reference

Implements the class Div2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_div_1d.h"
#include "mtk_div_2d.h"
```

Include dependency graph for mtk_div_2d.cc:




### 17.75.1 Detailed Description

This class implements a 2D divergence matrix operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_2d.cc.

## 17.76 mtk_div_2d.cc

```
00001
00011 /*
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00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
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00030
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00043 parties intellectual property rights.
```

```
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_1d.h"
00066 #include "mtk_div_1d.h"
00067 #include "mtk_div_2d.h"
00068
00069 mtk::Div2D::Div2D():
00070   order_accuracy_(),
00071   mimetic_threshold_() {}
00072
00073 mtk::Div2D::Div2D(const Div2D &div):
00074   order_accuracy_(div.order_accuracy_),
00075   mimetic_threshold_(div.mimetic_threshold_) {}
00076
00077 mtk::Div2D::~Div2D() {}
00078
00079 bool mtk::Div2D::ConstructDiv2D(const
      mtk::UniStgGrid2D &grid,
00080                                 int order_accuracy,
00081                                 mtk::Real mimetic_threshold) {
00082
00083   int num_cells_x = grid.num_cells_x();
00084   int num_cells_y = grid.num_cells_y();
00085
00086   int mx = num_cells_x + 2;  // Dx vertical dimension.
00087   int nx = num_cells_x + 1;  // Dx horizontal dimension.
00088   int my = num_cells_y + 2;  // Dy vertical dimension.
00089   int ny = num_cells_y + 1;  // Dy horizontal dimension.
00090
00091   mtk::Div1D div;
00092
00093   bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00094
00095   #ifdef MTK_PERFORM_PREVENTIONS
00096   if (!info) {
00097     std::cerr << "Mimetic div could not be built." << std::endl;
00098     return info;
00099   }
00100   #endif
00101
00102   auto west = grid.west_bndy();
00103   auto east = grid.east_bndy();
00104   auto south = grid.south_bndy();
00105   auto north = grid.east_bndy();
00106
00107   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00108   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00109
00110   mtk::DenseMatrix dx(div.ReturnAsDenseMatrix(grid_x));
00111   mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00112
00113   bool padded{true};
00114   bool transpose{false};
00115
00116   mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00117   mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00118
00119   mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00120   mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00121
00122   #if MTK_VERBOSE_LEVEL > 2
00123   std::cout << "Dx: " << mx << " by " << nx << std::endl;
```

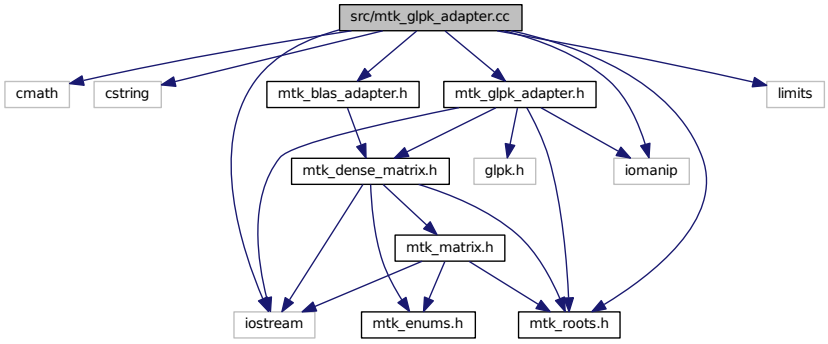
```
00124   std::cout << "Iy : " << num_cells_y<< " by " << ny  << std::endl;
00125   std::cout << "Dy: " << my << " by " << ny << std::endl;
00126   std::cout << "Ix : " << num_cells_x<< " by " << nx  << std::endl;
00127   std::cout << "Div 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00128     nx*ny <<std::endl;
00129   #endif
00130
00131   mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00132
00133   for (auto ii = 0; ii < mx*my; ii++) {
00134     for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00135       d2d.SetValue(ii, jj, dxy.GetValue(ii,jj));
00136     }
00137     for(auto kk=0; kk<ny*num_cells_x; kk++) {
00138       d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00139     }
00140   }
00141
00142   divergence_ = d2d;
00143
00144   return info;
00145 }
00146
00147 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix() const {
00148
00149   return divergence_;
00150 }
```

## 17.77 src/mtk_glpk_adapter.cc File Reference

Adapter class for the GLPK API.

```
#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include "mtk_roots.h"
#include "mtk_blas_adapter.h"
#include "mtk_glpk_adapter.h"
```

Include dependency graph for mtk_glpk_adapter.cc:



### 17.77.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the GLPK.

The **GLPK (GNU Linear Programming Kit)** package is intended for solving large-scale linear programming (LP), mixed integer programming (MIP), and other related problems. It is a set of routines written in ANSI C and organized in the form of a callable library.

**See also**

http://www.gnu.org/software/glpk/

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_glpk_adapter.cc.

## 17.78 mtk_glpk_adapter.cc

```
00001
00019 /*
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00022
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00024 are permitted provided that the following conditions are met:
00025
00026 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #include <cmath>
```

```
00066 #include <cstring>
00067
00068 #include <iostream>
00069 #include <iomanip>
00070 #include <limits>
00071
00072 #include "mtk_roots.h"
00073 #include "mtk_blas_adapter.h"
00074 #include "mtk_glpk_adapter.h"
00075
00076 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
      mtk::Real *A,
00077                                                    int nrows,
00078                                                    int ncols,
00079                                                    int kk,
00080                                                    mtk::Real *hh,
00081                                                    mtk::Real *qq,
00082                                                    int robjective,
00083                                                    mtk::Real mimetic_threshold,
00084                                                    int copy) {
00085
00086   #if MTK_DEBUG_LEVEL > 0
00087   char mps_file_name[18]; // File name for the MPS files.
00088   #endif
00089   char rname[5];          // Row name.
00090   char cname[5];          // Column name.
00091
00092   glp_prob *lp; // Linear programming problem.
00093
00094   int *ia;  // Array for the problem.
00095   int *ja;  // Array for the problem.
00096
00097   int problem_size; // Size of the problem.
00098   int lp_nrows;     // Number of rows.
00099   int lp_ncols;     // Number of columns.
00100   int matsize;      // Size of the matrix.
00101   int glp_index{1}; // Index of the objective function.
00102   int ii;           // Iterator.
00103   int jj;           // Iterator.
00104
00105   mtk::Real *ar;            // Array for the problem.
00106   mtk::Real *objective;     // Array containing the objective function.
00107   mtk::Real *rhs;           // Array containing the rhs.
00108   mtk::Real *err;           // Array of errors.
00109
00110   mtk::Real xl;             // Norm-2 of the error.
00111
00112   #if MTK_DEBUG_LEVEL > 0
00113   mtk::Real obj_value;      // Value of the objective function.
00114   #endif
00115
00116   lp_nrows = kk;
00117   lp_ncols = kk;
00118
00119   matsize = lp_nrows*lp_ncols;
00120
00122
00124   problem_size = lp_nrows*lp_ncols + 1;
00125
00126   try {
00127     ia = new int[problem_size];
00128   } catch (std::bad_alloc &memory_allocation_exception) {
00129     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00130       std::endl;
00131     std::cerr << memory_allocation_exception.what() << std::endl;
00132   }
00133   memset(ia, 0, sizeof(ia[0])*problem_size);
00134
00135   try {
00136     ja = new int[problem_size];
00137   } catch (std::bad_alloc &memory_allocation_exception) {
00138     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00139       std::endl;
00140     std::cerr << memory_allocation_exception.what() << std::endl;
00141   }
00142   memset(ja, 0, sizeof(ja[0])*problem_size);
00143
00144   try {
00145     ar = new mtk::Real[problem_size];
00146   } catch (std::bad_alloc &memory_allocation_exception) {
00147     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
```

```
00148       std::endl;
00149     std::cerr << memory_allocation_exception.what() << std::endl;
00150   }
00151   memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00152
00153   try {
00154     objective = new mtk::Real[lp_ncols + 1];
00155   } catch (std::bad_alloc &memory_allocation_exception) {
00156     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00157       std::endl;
00158     std::cerr << memory_allocation_exception.what() << std::endl;
00159   }
00160   memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00161
00162   try {
00163     rhs = new mtk::Real[lp_nrows + 1];
00164   } catch (std::bad_alloc &memory_allocation_exception) {
00165     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00166       std::endl;
00167     std::cerr << memory_allocation_exception.what() << std::endl;
00168   }
00169   memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00170
00171   try {
00172     err = new mtk::Real[lp_nrows];
00173   } catch (std::bad_alloc &memory_allocation_exception) {
00174     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00175       std::endl;
00176     std::cerr << memory_allocation_exception.what() << std::endl;
00177   }
00178   memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00179
00180   #if MTK_DEBUG_LEVEL > 0
00181   std::cout << "Problem size: " << problem_size << std::endl;
00182   std::cout << "lp_nrows = " << lp_nrows << std::endl;
00183   std::cout << "lp_ncols = " << lp_ncols << std::endl;
00184   std::cout << std::endl;
00185   #endif
00186
00187   lp = glp_create_prob();
00188
00189   glp_set_prob_name (lp, "mtk::GLPKAdapter::Simplex");
00190
00191   glp_set_obj_dir (lp, GLP_MIN);
00192
00194
00195   glp_add_rows(lp, lp_nrows);
00196
00197   for (ii = 1; ii <= lp_nrows; ++ii) {
00198     sprintf(rname, "R%02d",ii);
00199     glp_set_row_name(lp, ii, rname);
00200   }
00201
00202   glp_add_cols(lp, lp_ncols);
00203
00204   for (ii = 1; ii <= lp_ncols; ++ii) {
00205     sprintf(cname, "Q%02d",ii);
00206     glp_set_col_name (lp, ii, cname);
00207   }
00208
00210
00211   #if MTK_DEBUG_LEVEL>0
00212   std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00213   #endif
00214   for (jj = 0; jj < kk; ++jj) {
00215     objective[glp_index] = A[jj + robjective * ncols];
00216     glp_index++;
00217   }
00218   #if MTK_DEBUG_LEVEL >0
00219   std::cout << std::endl;
00220   #endif
00221
00223
00224   glp_index = 1;
00225   rhs[0] = mtk::kZero;
00226   for (ii = 0; ii <= lp_nrows; ++ii) {
00227     if (ii != robjective) {
00228       rhs[glp_index] = hh[ii];
00229       glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00230       glp_index++;
00231     }
```

```
00232   }
00233
00234   #if MTK_DEBUG_LEVEL > 0
00235   std::cout << "rhs =" << std::endl;
00236   for (auto ii = 0; ii < lp_nrows; ++ii) {
00237     std::cout << std::setw(15) << rhs[ii] << std::endl;
00238   }
00239   std::cout << std::endl;
00240   #endif
00241
00243
00244   for (ii = 1; ii <= lp_ncols; ++ii) {
00245     glp_set_obj_coef (lp, ii, objective[ii]);
00246   }
00247
00249
00250   for (ii = 1; ii <= lp_ncols; ++ii) {
00251     glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00252   }
00253
00255
00256   glp_index = 1;
00257   for (ii = 0; ii <= kk; ++ii) {
00258     for (jj = 0; jj < kk; ++jj) {
00259       if (ii != robjective) {
00260         ar[glp_index] = A[jj + ii * ncols];
00261         glp_index++;
00262       }
00263     }
00264   }
00265
00266   glp_index = 0;
00267
00268   for (ii = 1; ii < problem_size; ++ii) {
00269     if (((ii - 1) % lp_ncols) == 0) {
00270       glp_index++;
00271     }
00272     ia[ii] = glp_index;
00273     ja[ii] = (ii - 1) % lp_ncols + 1;
00274   }
00275
00276   glp_load_matrix (lp, matsize, ia, ja, ar);
00277
00278   #if MTK_DEBUG_LEVEL > 0
00279   sprintf(mps_file_name, "LP_MPS_row_%02d.mps", robjective);
00280   glp_write_mps(lp, GLP_MPS_FILE, nullptr, mps_file_name);
00281   #endif
00282
00284
00285   glp_simplex (lp, nullptr);
00286
00287   // Check status of the solution.
00288
00289   if (glp_get_status(lp) == GLP_OPT) {
00290
00291     for(ii = 1; ii <= lp_ncols; ++ii) {
00292       err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp,ii);
00293     }
00294
00295     #if MTK_DEBUG_LEVEL > 0
00296     obj_value = glp_get_obj_val (lp);
00297     std::cout << std::setw(12) << "CBS" << std::setw(12) << "CRS" << std::endl;
00298     for (ii = 0; ii < lp_ncols; ++ii) {
00299       std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00300         glp_get_col_prim(lp,ii + 1) << std::setw(12) << qq[ii] << std::endl;
00301     }
00302     std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00303       obj_value << std::endl;
00304     #endif
00305
00306     if (copy) {
00307       for(ii = 0; ii < lp_ncols; ++ii) {
00308         qq[ii] = glp_get_col_prim(lp,ii + 1);
00309       }
00310       // Preserve the bottom values of qq.
00311     }
00312
00313     x1 = mtk::BLASAdapter::RealNRM2(err,lp_ncols);
00314
00315   } else {
00316     x1 = std::numeric_limits<mtk::Real>::infinity();
```

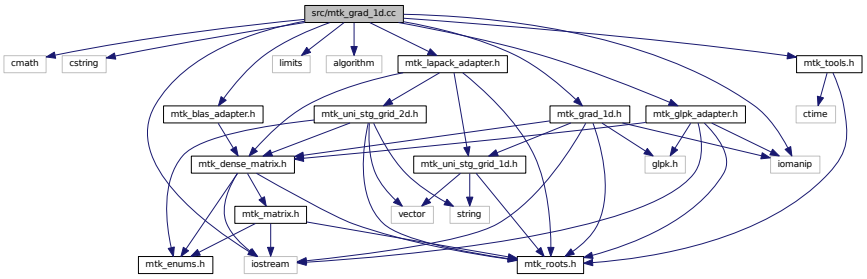
```
00317   }
00318
00319   glp_delete_prob (lp);
00320   glp_free_env ();
00321
00322   delete [] ia;
00323   delete [] ja;
00324   delete [] ar;
00325   delete [] objective;
00326   delete [] rhs;
00327   delete [] err;
00328
00329   return x1;
00330 }
```

## 17.79 src/mtk_grad_1d.cc File Reference

Implements the class Grad1D.

```
#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_grad_1d.h"
```

Include dependency graph for mtk_grad_1d.cc:




### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::Grad1D &in)

### 17.79.1 Detailed Description

This class implements a 1D gradient matrix operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm.

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**Todo** Overload ostream operator as in mtk::Lap1D.

**Todo** Implement creation of ■ w. mtk::BLASAdapter.

Definition in file mtk_grad_1d.cc.

## 17.80 mtk_grad_1d.cc

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
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00033 other materials provided with the distribution.
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00048
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00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
```

```
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
00075 #include "mtk_grad_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Grad1D &in) {
00080
00082
00083   stream << "gradient_[0] = " << std::setw(9) << in.gradient_[0] << std::endl;
00084
00086
00087   stream << "gradient_[1:" << in.order_accuracy_ << "] = ";
00088   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00089     stream << std::setw(9) << in.gradient_[ii] << " ";
00090   }
00091   stream << std::endl;
00092
00094
00095   stream << "gradient_[" << in.order_accuracy_ + 1 << ":" <<
00096     2*in.order_accuracy_ << "] = ";
00097   for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00098     stream << std::setw(9) << in.gradient_[ii] << " ";
00099   }
00100   stream << std::endl;
00101
00103
00104   int offset{2*in.order_accuracy_ + 1};
00105   int mm {};
00106
00107   stream << "gradient_[" << offset + mm << ":" <<
00108     offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00109
00110   if (in.order_accuracy_ > mtk::kDefaultOrderAccuracy) {
00111     for (auto ii = 0; ii < in.num_bndy_approxs_ ; ++ii) {
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; jj++) {
00113         auto value = in.gradient_[offset + (mm)];
00114         stream << std::setw(9) << value << " ";
00115         mm++;
00116       }
00117     }
00118   } else {
00119     stream << std::setw(9) << in.gradient_[offset + 0] << ' ';
00120     stream << std::setw(9) << in.gradient_[offset + 1] << ' ';
00121     stream << std::setw(9) << in.gradient_[offset + 2] << ' ';
00122   }
00123   stream << std::endl;
00124
00125   return stream;
00126 }
00127 }
00128
00129 mtk::Grad1D::Grad1D():
00130   order_accuracy_(mtk::kDefaultOrderAccuracy),
00131   dim_null_(),
00132   num_bndy_approxs_(),
00133   num_bndy_coeffs_(),
00134   gradient_length_(),
00135   minrow_(),
00136   row_(),
00137   coeffs_interior_(),
00138   prem_apps_(),
00139   weights_crs_(),
00140   weights_cbs_(),
00141   mim_bndy_(),
00142   gradient_(),
00143   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00144
00145 mtk::Grad1D::Grad1D(const Grad1D &grad):
00146   order_accuracy_(grad.order_accuracy_),
00147   dim_null_(grad.dim_null_),
00148   num_bndy_approxs_(grad.num_bndy_approxs_),
00149   num_bndy_coeffs_(grad.num_bndy_coeffs_),
00150   gradient_length_(grad.gradient_length_),
```

```
00151   minrow_(grad.minrow_),
00152   row_(grad.row_),
00153   coeffs_interior_(grad.coeffs_interior_),
00154   prem_apps_(grad.prem_apps_),
00155   weights_crs_(grad.weights_crs_),
00156   weights_cbs_(grad.weights_cbs_),
00157   mim_bndy_(grad.mim_bndy_),
00158   gradient_(grad.gradient_),
00159   mimetic_threshold_(grad.mimetic_threshold_) {}
00160
00161 mtk::Grad1D::~Grad1D() {
00162
00163   delete[] coeffs_interior_;
00164   coeffs_interior_ = nullptr;
00165
00166   delete[] prem_apps_;
00167   prem_apps_ = nullptr;
00168
00169   delete[] weights_crs_;
00170   weights_crs_ = nullptr;
00171
00172   delete[] weights_cbs_;
00173   weights_cbs_ = nullptr;
00174
00175   delete[] mim_bndy_;
00176   mim_bndy_ = nullptr;
00177
00178   delete[] gradient_;
00179   gradient_ = nullptr;
00180 }
00181
00182 bool mtk::Grad1D::ConstructGrad1D(int order_accuracy,
      Real mimetic_threshold) {
00183
00184   #ifdef MTK_PERFORM_PREVENTIONS
00185   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00186   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00187   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00188                       __FILE__, __LINE__, __func__);
00189
00190   if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00191     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00192   }
00193
00194   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00195   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00196   #endif
00197
00198   order_accuracy_ = order_accuracy;
00199   mimetic_threshold_ = mimetic_threshold;
00200
00202   bool abort_construction = ComputeStencilInteriorGrid();
00203
00204   #ifdef MTK_PERFORM_PREVENTIONS
00205   if (!abort_construction) {
00206     std::cerr << "Could NOT complete stage 1." << std::endl;
00207     std::cerr << "Exiting..." << std::endl;
00208     return false;
00209   }
00210   #endif
00211
00212   // At this point, we already have the values for the interior stencil stored
00213   // in the coeffs_interior_ array.
00214
00215   dim_null_ = order_accuracy_/2 - 1;
00216
00217   num_bndy_approxs_ = dim_null_ + 1;
00218
00219   #ifdef MTK_PRECISION_DOUBLE
00220   num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00221   #else
00222   num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00223   #endif
00224
00226
00227   // For this we will follow recommendations given in:
00228   //
00229   // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00230   //
00231   // We will compute the QR Factorization of the transpose, as in the
00232   // following (MATLAB) pseudo-code:
```

```
00233   //
00234   // [Q,R] = qr(V'); % Full QR as defined in
00235   // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00236   //
00237   // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00238   //
00239   // However, given the nature of the Vandermonde matrices we've just
00240   // computed, they all posses the same null-space. Therefore, we impose the
00241   // convention of computing the null-space of the first Vandermonde matrix
00242   // (west boundary).
00243
00244   // In the case of the gradient, the first Vandermonde system has a unique
00245   // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00246   // matrix used to assemble said system, will have an empty null-space.
00247
00248   // Therefore, we only compute a rational basis for the case of order higher
00249   // than second.
00250
00251   if (dim_null_ > 0) {
00252
00253     abort_construction = ComputeRationalBasisNullSpace();
00254
00255     #ifdef MTK_PERFORM_PREVENTIONS
00256     if (!abort_construction) {
00257       std::cerr << "Could NOT complete stage 2.1." << std::endl;
00258       std::cerr << "Exiting..." << std::endl;
00259       return false;
00260     }
00261     #endif
00262   }
00263
00265   abort_construction = ComputePreliminaryApproximations();
00266
00267   #ifdef MTK_PERFORM_PREVENTIONS
00268   if (!abort_construction) {
00269     std::cerr << "Could NOT complete stage 2.2." << std::endl;
00270     std::cerr << "Exiting..." << std::endl;
00271     return false;
00272   }
00273   #endif
00274
00276   abort_construction = ComputeWeights();
00277
00278   #ifdef MTK_PERFORM_PREVENTIONS
00279   if (!abort_construction) {
00280     std::cerr << "Could NOT complete stage 2.3." << std::endl;
00281     std::cerr << "Exiting..." << std::endl;
00282     return false;
00283   }
00284   #endif
00285
00287   if (dim_null_ > 0) {
00288
00289     abort_construction = ComputeStencilBoundaryGrid();
00290
00291     #ifdef MTK_PERFORM_PREVENTIONS
00292     if (!abort_construction) {
00293       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00294       std::cerr << "Exiting..." << std::endl;
00295       return false;
00296     }
00297     #endif
00298   }
00299
00301
00302   // Once we have the following three collections of data:
00303   //   (a) the coefficients for the interior,
00304   //   (b) the coefficients for the boundary (if it applies),
00305   //   (c) and the weights (if it applies),
00306   // we will store everything in the output array:
00307
00308   abort_construction = AssembleOperator();
00309
00310   #ifdef MTK_PERFORM_PREVENTIONS
00311   if (!abort_construction) {
00312     std::cerr << "Could NOT complete stage 3." << std::endl;
00313     std::cerr << "Exiting..." << std::endl;
00314     return false;
00315   }
00316   #endif
00317
```

```
00318   return true;
00319 }
00320
00321 int mtk::Grad1D::num_bndy_coeffs() const {
00322
00323   return num_bndy_coeffs_;
00324 }
00325
00326 mtk::Real *mtk::Grad1D::coeffs_interior() const {
00327
00328   return coeffs_interior_;
00329 }
00330
00331 mtk::Real *mtk::Grad1D::weights_crs() const {
00332
00333   return weights_crs_;
00334 }
00335
00336 mtk::Real *mtk::Grad1D::weights_cbs() const {
00337
00338   return weights_cbs_;
00339 }
00340
00341 mtk::DenseMatrix mtk::Grad1D::mim_bndy() const {
00342
00343   mtk::DenseMatrix xx(dim_null_ + 1, 3*order_accuracy_/2);
00344
00345   auto counter = 0;
00346   for (auto ii = 0; ii < dim_null_ + 1; ++ii) {
00347     for(auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00348       xx.SetValue(ii,jj, gradient_[2*order_accuracy_ + 1 + counter]);
00349       counter++;
00350     }
00351   }
00352
00353   return xx;
00354 }
00355
00356 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
      mtk::Real west,
00357                                                   mtk::Real east,
00358                                                   int num_cells_x) const {
00359
00360   int nn{num_cells_x}; // Number of cells on the grid.
00361
00362   #ifdef MTK_PERFORM_PREVENTIONS
00363   mtk::Tools::Prevent(east < west, __FILE__, __LINE__, __func__);
00364   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00365   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00366   #endif
00367
00368   mtk::Real delta_x = (east - west)/((mtk::Real) num_cells_x);
00369
00370   mtk::Real inv_delta_x{mtk::kOne/delta_x};
00371
00372   int gg_num_rows = nn + 1;
00373   int gg_num_cols = nn + 2;
00374   int elements_per_row = num_bndy_coeffs_;
00375   int num_extra_rows = order_accuracy_/2;
00376
00377   // Output matrix featuring sizes for gradient operators.
00378   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00379
00381
00382   auto ee_index = 0;
00383   for (auto ii = 0; ii < num_extra_rows; ii++) {
00384     auto cc = 0;
00385     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00386       if(cc >= elements_per_row) {
00387         out.SetValue(ii, jj, mtk::kZero);
00388       } else {
00389         out.SetValue(ii,jj,
00390                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00391         cc++;
00392       }
00393     }
00394   }
00395
00397
00398   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00399     auto jj = ii - num_extra_rows + 1;
```

```
00400     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00401       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00402     }
00403   }
00404 
00406 
00407   ee_index = 0;
00408   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00409     auto cc = 0;
00410     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00411       if(cc >= elements_per_row) {
00412         out.SetValue(ii,jj,mtk::kZero);
00413       } else {
00414         out.SetValue(ii,jj,
00415                      -gradient_[2*order_accuracy_ + 1 +
00416 ee_index++]*inv_delta_x);
00417         cc++;
00418       }
00419      }
00420   }
00421 
00422   return out;
00423 }
00424 
00425 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
00426   const UniStgGrid1D &grid) const {
00427 
00428   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00429 
00430   #ifdef MTK_PERFORM_PREVENTIONS
00431   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00432   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00433   #endif
00434 
00435   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00436 
00437   int gg_num_rows = nn + 1;
00438   int gg_num_cols = nn + 2;
00439   int elements_per_row = num_bndy_coeffs_;
00440   int num_extra_rows = order_accuracy_/2;
00441 
00442   // Output matrix featuring sizes for gradient operators.
00443   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00444 
00446 
00447   auto ee_index = 0;
00448   for (auto ii = 0; ii < num_extra_rows; ii++) {
00449     auto cc = 0;
00450     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00451       if(cc >= elements_per_row) {
00452         out.SetValue(ii, jj, mtk::kZero);
00453       } else {
00454         out.SetValue(ii,jj,
00455                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00456         cc++;
00457       }
00458     }
00459   }
00460 
00462 
00463   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00464     auto jj = ii - num_extra_rows + 1;
00465     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00466       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00467     }
00468   }
00469 
00471 
00472   ee_index = 0;
00473   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00474     auto cc = 0;
00475     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00476       if(cc >= elements_per_row) {
00477         out.SetValue(ii,jj,mtk::kZero);
00478       } else {
00479         out.SetValue(ii,jj,
00480                      -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00481         cc++;
00482       }
00483      }
00484   }
```

```
00485
00486   return out;
00487 }
00488
00489 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix
      (
00490   int num_cells_x) const {
00491
00492   int nn{num_cells_x}; // Number of cells on the grid.
00493
00494   #ifdef MTK_PERFORM_PREVENTIONS
00495   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00496   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00497   #endif
00498
00499   int gg_num_rows = nn + 1;
00500   int gg_num_cols = nn + 2;
00501   int elements_per_row = num_bndy_coeffs_;
00502   int num_extra_rows = order_accuracy_/2;
00503
00504   // Output matrix featuring sizes for gradient operators.
00505   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00506
00508
00509   auto ee_index = 0;
00510   for (auto ii = 0; ii < num_extra_rows; ii++) {
00511     auto cc = 0;
00512     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00513       if(cc >= elements_per_row) {
00514         out.SetValue(ii, jj, mtk::kZero);
00515       } else {
00516         out.SetValue(ii,jj,
00517                      gradient_[2*order_accuracy_ + 1 + ee_index++]);
00518         cc++;
00519       }
00520     }
00521   }
00522
00524
00525   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00526     auto jj = ii - num_extra_rows + 1;
00527     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00528       out.SetValue(ii, jj, coeffs_interior_[cc]);
00529     }
00530   }
00531
00533
00534   ee_index = 0;
00535   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00536     auto cc = 0;
00537     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00538       if(cc >= elements_per_row) {
00539         out.SetValue(ii,jj,mtk::kZero);
00540       } else {
00541         out.SetValue(ii,jj,
00542                      -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00543         cc++;
00544       }
00545      }
00546   }
00547
00548   return out;
00549 }
00550
00551 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00552
00554
00555   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00556
00557   try {
00558     pp = new mtk::Real[order_accuracy_];
00559   } catch (std::bad_alloc &memory_allocation_exception) {
00560     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00561       std::endl;
00562     std::cerr << memory_allocation_exception.what() << std::endl;
00563   }
00564   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00565
00566   #ifdef MTK_PRECISION_DOUBLE
00567   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00568   #else
```

```
00569   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00570   #endif
00571
00572   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00573     pp[ii] = pp[ii - 1] + mtk::kOne;
00574   }
00575
00576   #if MTK_VERBOSE_LEVEL > 3
00577   std::cout << "pp =" << std::endl;
00578   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00579     std::cout << std::setw(12) << pp[ii];
00580   }
00581   std::cout << std::endl << std::endl;
00582   #endif
00583
00585
00586   bool transpose{false};
00587
00588   mtk::DenseMatrix vander_matrix(pp,order_accuracy_,order_accuracy_,transpose);
00589
00590   #if MTK_VERBOSE_LEVEL > 4
00591   std::cout << "vander_matrix = " << std::endl;
00592   std::cout << vander_matrix << std::endl << std::endl;
00593   #endif
00594
00596
00597   try {
00598     coeffs_interior_ = new mtk::Real[order_accuracy_];
00599   } catch (std::bad_alloc &memory_allocation_exception) {
00600     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00601       std::endl;
00602     std::cerr << memory_allocation_exception.what() << std::endl;
00603   }
00604   memset(coeffs_interior_, mtk::kZero,
00605 sizeof(coeffs_interior_[0])*order_accuracy_);
00606
00607   coeffs_interior_[1] = mtk::kOne;
00608
00609   #if MTK_VERBOSE_LEVEL > 3
00610   std::cout << "oo =" << std::endl;
00611   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00612     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00613   }
00614   std::cout << std::endl;
00615   #endif
00616
00618
00619   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00620                                                 coeffs_interior_)};
00621
00622   #ifdef MTK_PERFORM_PREVENTIONS
00623   if (!info) {
00624     std::cout << "System solved! Interior stencil attained!" << std::endl;
00625     std::cout << std::endl;
00626   }
00627   else {
00628     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00629     std::cerr << "Exiting..." << std::endl;
00630     return false;
00631   }
00632   #endif
00633
00634   #if MTK_VERBOSE_LEVEL > 3
00635   std::cout << "coeffs_interior_ =" << std::endl;
00636   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00637     std::cout << std::setw(12) << coeffs_interior_[ii];
00638   }
00639   std::cout << std::endl << std::endl;
00640   #endif
00641
00642   delete [] pp;
00643   pp = nullptr;
00644
00645   return true;
00646 }
00647
00648 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00649
00651
00652   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00653
```

```
00654   try {
00655     gg = new mtk::Real[num_bndy_coeffs_];
00656   } catch (std::bad_alloc &memory_allocation_exception) {
00657     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00658       std::endl;
00659     std::cerr << memory_allocation_exception.what() << std::endl;
00660   }
00661   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00662
00663   #ifdef MTK_PRECISION_DOUBLE
00664   gg[1] = 1.0/2.0;
00665   #else
00666   gg[1] = 1.0f/2.0f;
00667   #endif
00668   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00669     gg[ii] = gg[ii - 1] + mtk::kOne;
00670   }
00671
00672   #if MTK_VERBOSE_LEVEL > 3
00673   std::cout << "gg =" << std::endl;
00674   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00675     std::cout << std::setw(12) << gg[ii];
00676   }
00677   std::cout << std::endl << std::endl;
00678   #endif
00679
00680
00681
00682   bool tran{true}; // Should I transpose the Vandermonde matrix.
00683
00684   mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00685
00686   #if MTK_VERBOSE_LEVEL > 4
00687   std::cout << "aa_west_t =" << std::endl;
00688   std::cout << aa_west_t << std::endl;
00689   #endif
00690
00691
00692
00693   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (aa_west_t));
00694
00695   #if MTK_VERBOSE_LEVEL > 3
00696   std::cout << "qq_t = " << std::endl;
00697   std::cout << qq_t << std::endl;
00698   #endif
00699
00700
00701
00702   int kk_num_rows{num_bndy_coeffs_};
00703   int kk_num_cols{dim_null_};
00704
00705   mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00706
00707   // In the case of the gradient, even though we must solve for a null-space
00708   // of dimension 2, we must only extract ONE basis for the kernel.
00709   // We perform this extraction here:
00710
00711   int aux_{kk_num_rows - kk_num_cols};
00712   for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00713     aux_--;
00714     for (auto jj = 0; jj < kk_num_rows; jj++) {
00715       kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00716         qq_t.data()[ii*num_bndy_coeffs_ + jj];
00717     }
00718   }
00719
00720   #if MTK_VERBOSE_LEVEL > 2
00721   std::cout << "kk =" << std::endl;
00722   std::cout << kk << std::endl;
00723   std::cout << "kk.num_rows() = " << kk.num_rows() << std::endl;
00724   std::cout << "kk.num_cols() = " << kk.num_cols() << std::endl;
00725   std::cout << std::endl;
00726   #endif
00727
00729
00730   // Scale thus requesting that the last entries of the attained basis for the
00731   // null-space, adopt the pattern we require.
00732   // Essentially we will implement the following MATLAB pseudo-code:
00733   //  scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00734   //  SK = kk*scalers
00735   // where SK is the scaled null-space.
00736
00737   // In this point, we almost have all the data we need correctly allocated
```

```
00738   // in memory. We will create the matrix iden_, and elements we wish to scale
00739   // in the kk array. Using the concept of the leading dimension, we could just
00740   // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00741   // GET how does it work. So I will just create a matrix with the content of
00742   // this array that we need, solve for the scalers and then scale the
00743   // whole kk:
00744
00745   // We will then create memory for that sub-matrix of kk (subk).
00746
00747   mtk::DenseMatrix subk(dim_null_, dim_null_);
00748
00749   auto zz = 0;
00750   for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00751     for (auto jj = 0; jj < dim_null_; jj++) {
00752       subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00753     }
00754     zz++;
00755   }
00756
00757   #if MTK_VERBOSE_LEVEL > 4
00758   std::cout << "subk =" << std::endl;
00759   std::cout << subk << std::endl;
00760   #endif
00761
00762   subk.Transpose();
00763
00764   #if MTK_VERBOSE_LEVEL > 4
00765   std::cout << "subk_t =" << std::endl;
00766   std::cout << subk << std::endl;
00767   #endif
00768
00769   bool padded{false};
00770   tran = false;
00771
00772   mtk::DenseMatrix iden(dim_null_, padded, tran);
00773
00774   #if MTK_VERBOSE_LEVEL > 4
00775   std::cout << "iden =" << std::endl;
00776   std::cout << iden << std::endl;
00777   #endif
00778
00779   // Solve the system to compute the scalers.
00780   // An example of the system to solve, for k = 8, is:
00781   //
00782   // subk*scalers = iden or
00783   //
00784   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00785   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00786   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00787   //
00788   // Notice this is a nrhs = 3 system.
00789   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00790   // will be stored in the created identity matrix.
00791   // Let us first transpose subk (because of LAPACK):
00792
00793   int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00794
00795   #ifdef MTK_PERFORM_PREVENTIONS
00796   if (!info) {
00797     std::cout << "System successfully solved!" <<
00798       std::endl;
00799   } else {
00800     std::cerr << "Something went wrong solving system! info = " << info <<
00801       std::endl;
00802     std::cerr << "Exiting..." << std::endl;
00803     return false;
00804   }
00805   std::cout << std::endl;
00806   #endif
00807
00808   #if MTK_VERBOSE_LEVEL > 4
00809   std::cout << "Computed scalers:" << std::endl;
00810   std::cout << iden << std::endl;
00811   #endif
00812
00813   // Multiply the two matrices to attain a scaled basis for null-space.
00814
00815   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00816
00817   #if MTK_VERBOSE_LEVEL > 4
00818   std::cout << "Rational basis for the null-space:" << std::endl;
```

```
00819   std::cout << rat_basis_null_space_ << std::endl;
00820   #endif
00821
00822   // At this point, we have a rational basis for the null-space, with the
00823   // pattern we need! :)
00824
00825   delete [] gg;
00826   gg = nullptr;
00827
00828   return true;
00829 }
00830
00831 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00832
00834
00835   mtk::Real *gg{}; // Generator vector for the first approximation.
00836
00837   try {
00838     gg = new mtk::Real[num_bndy_coeffs_];
00839   } catch (std::bad_alloc &memory_allocation_exception) {
00840     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00841       std::endl;
00842     std::cerr << memory_allocation_exception.what() << std::endl;
00843   }
00844   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00845
00846   #ifdef MTK_PRECISION_DOUBLE
00847   gg[1] = 1.0/2.0;
00848   #else
00849   gg[1] = 1.0f/2.0f;
00850   #endif
00851   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00852     gg[ii] = gg[ii - 1] + mtk::kOne;
00853   }
00854
00855   #if MTK_VERBOSE_LEVEL > 3
00856   std::cout << "gg0 =" << std::endl;
00857   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00858     std::cout << std::setw(12) << gg[ii];
00859   }
00860   std::cout << std::endl << std::endl;
00861   #endif
00862
00863   // Allocate 2D array to store the collection of preliminary approximations.
00864   try {
00865     prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00866   } catch (std::bad_alloc &memory_allocation_exception) {
00867     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00868 std::endl;
00869     std::cerr << memory_allocation_exception.what() << std::endl;
00870   }
00871   memset(prem_apps_,
00872          mtk::kZero,
00873          sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00874
00876
00877   for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00878
00879     // Re-check new generator vector for every iteration except for the first.
00880     #if MTK_VERBOSE_LEVEL > 3
00881     if (ll > 0) {
00882       std::cout << "gg_" << ll << " =" << std::endl;
00883       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00884         std::cout << std::setw(12) << gg[ii];
00885       }
00886       std::cout << std::endl << std::endl;
00887     }
00888     #endif
00889
00891
00892     bool transpose{false};
00893
00894     mtk::DenseMatrix aa(gg,
00895                         num_bndy_coeffs_, order_accuracy_ + 1,
00896                         transpose);
00897
00898     #if MTK_VERBOSE_LEVEL > 4
00899     std::cout << "aa_" << ll << " =" << std::endl;
00900     std::cout << aa << std::endl;
00901     #endif
00902
```

```
00904
00905     mtk::Real *ob{};
00906
00907     auto ob_ld = num_bndy_coeffs_;
00908
00909     try {
00910       ob = new mtk::Real[ob_ld];
00911     } catch (std::bad_alloc &memory_allocation_exception) {
00912       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00913         std::endl;
00914       std::cerr << memory_allocation_exception.what() << std::endl;
00915     }
00916     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00917
00918     ob[1] = mtk::kOne;
00919
00920     #if MTK_VERBOSE_LEVEL > 3
00921     std::cout << "ob = " << std::endl << std::endl;
00922     for (auto ii = 0; ii < ob_ld; ++ii) {
00923       std::cout << std::setw(12) << ob[ii] << std::endl;
00924     }
00925     std::cout << std::endl;
00926     #endif
00927
00929
00930     // However, this is an under-determined system of equations. So we can not
00931     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00932     // our LAPACKAdapter class.
00933
00934     int info_{
00935       mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
      , ob_ld)};
00936
00937     #ifdef MTK_PERFORM_PREVENTIONS
00938     if (!info_) {
00939       std::cout << "System successfully solved!" << std::endl << std::endl;
00940     } else {
00941       std::cerr << "Error solving system! info = " << info_ << std::endl;
00942       return false;
00943     }
00944     #endif
00945
00946     #if MTK_VERBOSE_LEVEL > 3
00947     std::cout << "ob =" << std::endl;
00948     for (auto ii = 0; ii < ob_ld; ++ii) {
00949       std::cout << std::setw(12) << ob[ii] << std::endl;
00950     }
00951     std::cout << std::endl;
00952     #endif
00953
00955
00956     // This implies a DAXPY operation. However, we must construct the arguments
00957     // for this operation.
00958
00960     // Save them into the ob_bottom array:
00961
00962     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00963
00964     try {
00965       ob_bottom = new mtk::Real[dim_null_];
00966     } catch (std::bad_alloc &memory_allocation_exception) {
00967       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00968         std::endl;
00969       std::cerr << memory_allocation_exception.what() << std::endl;
00970     }
00971     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00972
00973     for (auto ii = 0; ii < dim_null_; ++ii) {
00974       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00975     }
00976
00977     #if MTK_VERBOSE_LEVEL > 3
00978     std::cout << "ob_bottom =" << std::endl;
00979     for (auto ii = 0; ii < dim_null_; ++ii) {
00980       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00981     }
00982     std::cout << std::endl;
00983     #endif
00984
00986
00987     // We must computed an scaled ob, sob, using the scaled null-space in
```

```
00988     // rat_basis_null_space_.
00989     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00990     // or:                 ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00991     // thus:                Y =    a*A    *x         +   b*Y (DAXPY).
00992
00993     #if MTK_VERBOSE_LEVEL > 4
00994     std::cout << "Rational basis for the null-space:" << std::endl;
00995     std::cout << rat_basis_null_space_ << std::endl;
00996     #endif
00997
00998     mtk::Real alpha{-mtk::kOne};
00999     mtk::Real beta{mtk::kOne};
01000
01001     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
01002                                   ob_bottom, beta, ob);
01003
01004     #if MTK_VERBOSE_LEVEL > 3
01005     std::cout << "scaled ob:" << std::endl;
01006     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01007       std::cout << std::setw(12) << ob[ii] << std::endl;
01008     }
01009     std::cout << std::endl;
01010     #endif
01011
01012     // We save the recently scaled solution, into an array containing these.
01013     // We can NOT start building the pi matrix, simply because I want that part
01014     // to be separated since its construction depends on the algorithm we want
01015     // to implement.
01016
01017     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01018       prem_apps_[ii*num_bndy_approxs_ + ll] = ob[ii];
01019     }
01020
01021     // After the first iteration, simply shift the entries of the last
01022     // generator vector used:
01023     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01024       gg[ii]--;
01025     }
01026
01027     // Garbage collection for this loop:
01028     delete[] ob;
01029     ob = nullptr;
01030
01031     delete[] ob_bottom;
01032     ob_bottom = nullptr;
01033   } // End of: for (ll = 0; ll < dim_null; ll++);
01034
01035   #if MTK_VERBOSE_LEVEL > 4
01036   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
01037   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01038     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01039       std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
01040     }
01041     std::cout << std::endl;
01042   }
01043   std::cout << std::endl;
01044   #endif
01045
01046   delete[] gg;
01047   gg = nullptr;
01048
01049   return true;
01050 }
01051
01052 bool mtk::Grad1D::ComputeWeights() {
01053
01054   // Matrix to compute the weights as in the CRSA.
01055   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01056
01058
01059   // Assemble the pi matrix using:
01060   // 1. The collection of scaled preliminary approximations.
01061   // 2. The collection of coefficients approximating at the interior.
01062   // 3. The scaled basis for the null-space.
01063
01064   // 1.1. Process array of scaled preliminary approximations.
01065
01066   // These are queued in scaled_solutions. Each one of these, will be a column
01067   // of the pi matrix:
01068   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01069     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
```

```
01070       pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
01071         prem_apps_[ii*num_bndy_approxs_ + jj];
01072     }
01073   }
01074
01075   // 1.2. Add columns from known stencil approximating at the interior.
01076
01077   // However, these must be padded by zeros, according to their position in the
01078   // final pi matrix:
01079   auto mm = 1;
01080   for (auto jj = num_bndy_approxs_; jj < order_accuracy_; ++jj) {
01081     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01082       auto de = (ii + mm)*(2*(num_bndy_approxs_ - 1) +
01083         (order_accuracy_/2 + 1)) + jj;
01084       pi.data()[de] = coeffs_interior_[ii];
01085     }
01086     ++mm;
01087   }
01088
01089   rat_basis_null_space_.OrderColMajor();
01090
01091   #if MTK_VERBOSE_LEVEL > 4
01092   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01093   std::cout << rat_basis_null_space_ << std::endl;
01094   #endif
01095
01096   // 1.3. Add final set of columns: rational basis for null-space.
01097
01098   for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
01099        jj < num_bndy_coeffs_ - 1; ++jj) {
01100     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01101       auto og =
01102         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
01103       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
01104       pi.data()[de] = rat_basis_null_space_.data()[og];
01105     }
01106   }
01107
01108   #if MTK_VERBOSE_LEVEL > 4
01109   std::cout << "coeffs_interior_ =" << std::endl;
01110   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01111     std::cout << std::setw(12) << coeffs_interior_[ii];
01112   }
01113   std::cout << std::endl << std::endl;
01114   #endif
01115
01116   #if MTK_VERBOSE_LEVEL > 4
01117   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01118   std::cout << pi << std::endl;
01119   #endif
01120
01122
01123   // This imposes the mimetic condition.
01124
01125   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
01126
01127   try {
01128     hh = new mtk::Real[num_bndy_coeffs_];
01129   } catch (std::bad_alloc &memory_allocation_exception) {
01130     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01131       std::endl;
01132     std::cerr << memory_allocation_exception.what() << std::endl;
01133   }
01134   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01135
01136   hh[0] = -mtk::kOne;
01137   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01138     auto aux_xx = mtk::kZero;
01139     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01140       aux_xx += coeffs_interior_[jj];
01141     }
01142     hh[ii] = -mtk::kOne*aux_xx;
01143   }
01144
01146
01147   // That is, we construct a system, to solve for the weights.
01148
01149   // Once again we face the challenge of solving with LAPACK. However, for the
01150   // CRSA, this matrix PI is over-determined, since it has more rows than
01151   // unknowns. However, according to the theory, the solution to this system is
01152   // unique. We will use dgels_.
```

```
01153
01154   try {
01155     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01156   } catch (std::bad_alloc &memory_allocation_exception) {
01157     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01158       std::endl;
01159     std::cerr << memory_allocation_exception.what() << std::endl;
01160   }
01161   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01162
01163   int weights_ld{pi.num_cols() + 1};
01164
01165   // Preserve hh.
01166   std::copy(hh, hh + weights_ld, weights_cbs_);
01167
01168   pi.Transpose();
01169
01170   int info{
01171     mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01172                                                     weights_cbs_, weights_ld)
01173   };
01174
01175   #ifdef MTK_PERFORM_PREVENTIONS
01176   if (!info) {
01177     std::cout << "System successfully solved!" << std::endl << std::endl;
01178   } else {
01179     std::cerr << "Error solving system! info = " << info << std::endl;
01180     return false;
01181   }
01182   #endif
01183
01184   #if MTK_VERBOSE_LEVEL > 3
01185   std::cout << "hh =" << std::endl;
01186   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01187     std::cout << std::setw(11) << hh[ii] << std::endl;
01188   }
01189   std::cout << std::endl;
01190   #endif
01191
01192   // Preserve the original weights for research.
01193
01194   try {
01195     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01196   } catch (std::bad_alloc &memory_allocation_exception) {
01197     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01198       std::endl;
01199     std::cerr << memory_allocation_exception.what() << std::endl;
01200   }
01201   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01202
01203   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01204
01205   #if MTK_VERBOSE_LEVEL > 3
01206   std::cout << "weights_CRSA + lambda =" << std::endl;
01207   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01208     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01209   }
01210   std::cout << std::endl;
01211   #endif
01212
01214
01215   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01216
01217     int minrow_{std::numeric_limits<int>::infinity()};
01218
01219     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
    order_accuracy_)};
01220     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01221
01223
01224     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01225
01226     // 6.1. Insert preliminary approximations to first set of columns.
01227
01228     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01229       for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01230         phi.data()[ii*(order_accuracy_) + jj] =
01231           prem_apps_[ii*num_bndy_approxs_ + jj];
01232       }
01233     }
01234
```

```
01235     // 6.2. Skip a column and negate preliminary approximations.
01236
01237     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01238       for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01239         auto de = (ii+ order_accuracy_ - num_bndy_approxs_+ jj*order_accuracy_);
01240         auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01241         phi.data()[de] = -prem_apps_[og];
01242       }
01243     }
01244
01245     // 6.3. Flip negative columns up-down.
01246
01247     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01248       for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01249         auto aux = phi.data()[ii*order_accuracy_ + jj];
01250         phi.data()[ii*order_accuracy_ + jj] =
01251           phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj];
01252         phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01253       }
01254     }
01255
01256     // 6.4. Insert stencil.
01257
01258     auto mm = 0;
01259     for (auto jj = num_bndy_approxs_; jj < num_bndy_approxs_ +  1; jj++) {
01260       for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01261         if (ii == 0) {
01262           phi.data()[jj] = 0.0;
01263         } else {
01264           phi.data()[(ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01265         }
01266       }
01267       mm++;
01268     }
01269
01270     #if MTK_VERBOSE_LEVEL > 4
01271     std::cout << "phi =" << std::endl;
01272     std::cout << phi << std::endl;
01273     #endif
01274
01276
01277     mtk::Real *lamed{};  // Used to build big lambda.
01278
01279     try {
01280       lamed = new mtk::Real[num_bndy_approxs_ - 1];
01281     } catch (std::bad_alloc &memory_allocation_exception) {
01282       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01283         std::endl;
01284       std::cerr << memory_allocation_exception.what() << std::endl;
01285     }
01286     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01287
01288     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01289       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01290     }
01291
01292     #if MTK_VERBOSE_LEVEL > 3
01293     std::cout << "lamed =" << std::endl;
01294     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01295       std::cout << std::setw(12) << lamed[ii] << std::endl;
01296     }
01297     std::cout << std::endl;
01298     #endif
01299
01300     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01301       mtk::Real temp = mtk::kZero;
01302       for(auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01303         temp = temp +
01304           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01305       }
01306       hh[ii] = hh[ii] - temp;
01307     }
01308
01309     #if MTK_VERBOSE_LEVEL > 3
01310     std::cout << "big_lambda =" << std::endl;
01311     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01312       std::cout << std::setw(12) << hh[ii] << std::endl;
01313     }
01314     std::cout << std::endl;
01315     #endif
01316
```

```
01318
01319     int copy_result{};  // Should I replace the solution... not for now.
01320
01321     mtk::Real normerr_; // Norm of the error for the solution on each row.
01322
01323     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01324       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01325                                                           order_accuracy_ + 1,
01326                                                           order_accuracy_,
01327                                                           order_accuracy_,
01328                                                           hh,
01329                                                           weights_cbs_,
01330                                                           row_,
01331                                                           mimetic_threshold_,
01332                                                           copy_result);
01333       mtk::Real aux{normerr_/norm};
01334
01335       #if MTK_VERBOSE_LEVEL > 2
01336       std::cout << "Relative norm: " << aux << " " << std::endl;
01337       std::cout << std::endl;
01338       #endif
01339
01340       if (aux < minnorm) {
01341         minnorm = aux;
01342         minrow_= row_;
01343       }
01344     }
01345
01346     #if MTK_VERBOSE_LEVEL > 3
01347     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01348       std::endl;
01349     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01350       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01351     }
01352     std::cout << std::endl;
01353     #endif
01354
01356
01357     // After we know which row yields the smallest relative norm that row is
01358     // chosen to be the objective function and the result of the optimizer is
01359     // chosen to be the new weights_.
01360
01361     #if MTK_VERBOSE_LEVEL > 2
01362     std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01363       minrow_ + 1 << std::endl;
01364     std::cout << std::endl;
01365     #endif
01366
01367     copy_result = 1;
01368     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01369                                                         order_accuracy_ + 1,
01370                                                         order_accuracy_,
01371                                                         order_accuracy_,
01372                                                         hh,
01373                                                         weights_cbs_,
01374                                                         minrow_,
01375                                                         mimetic_threshold_,
01376                                                         copy_result);
01377     mtk::Real aux_{normerr_/norm};
01378     #if MTK_VERBOSE_LEVEL > 2
01379     std::cout << "Relative norm: " << aux_ << std::endl;
01380     std::cout << std::endl;
01381     #endif
01382
01383     delete [] lamed;
01384     lamed = nullptr;
01385   }
01386
01387   delete [] hh;
01388   hh = nullptr;
01389
01390   return true;
01391 }
01392
01393 bool mtk::Grad1D::ComputeStencilBoundaryGrid(void) {
01394
01395   #if MTK_VERBOSE_LEVEL > 3
01396   std::cout << "weights_* + lambda =" << std::endl;
01397   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
```

```
01398     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01399   }
01400   std::cout << std::endl;
01401   #endif
01402
01404
01405   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01406
01407   try {
01408     lambda = new mtk::Real[dim_null_];
01409   } catch (std::bad_alloc &memory_allocation_exception) {
01410     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01411       std::endl;
01412     std::cerr << memory_allocation_exception.what() << std::endl;
01413   }
01414   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01415
01416   for (auto ii = 0; ii < dim_null_; ++ii) {
01417     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01418   }
01419
01420   #if MTK_VERBOSE_LEVEL > 3
01421   std::cout << "lambda =" << std::endl;
01422   for (auto ii = 0; ii < dim_null_; ++ii) {
01423     std::cout << std::setw(12) << lambda[ii] << std::endl;
01424   }
01425   std::cout << std::endl;
01426   #endif
01427
01429
01430   mtk::Real *alpha{}; // Collection of alpha values.
01431
01432   try {
01433     alpha = new mtk::Real[dim_null_];
01434   } catch (std::bad_alloc &memory_allocation_exception) {
01435     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01436       std::endl;
01437     std::cerr << memory_allocation_exception.what() << std::endl;
01438   }
01439   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01440
01441   for (auto ii = 0; ii < dim_null_; ++ii) {
01442     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01443   }
01444
01445   #if MTK_VERBOSE_LEVEL > 3
01446   std::cout << "alpha =" << std::endl;
01447   for (auto ii = 0; ii < dim_null_; ++ii) {
01448     std::cout << std::setw(12) << alpha[ii] << std::endl;
01449   }
01450   std::cout << std::endl;
01451   #endif
01452
01454
01455   try {
01456     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
01457   } catch (std::bad_alloc &memory_allocation_exception) {
01458     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01459       std::endl;
01460     std::cerr << memory_allocation_exception.what() << std::endl;
01461   }
01462   memset(mim_bndy_,
01463          mtk::kZero,
01464          sizeof(mim_bndy_[0])*num_bndy_coeffs_*num_bndy_approxs_);
01465
01466   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01467     for (auto jj = 0; jj < (num_bndy_approxs_ - 1); ++jj) {
01468       mim_bndy_[ii*num_bndy_approxs_ + jj] =
01469         prem_apps_[ii*num_bndy_approxs_ + jj] +
01470         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01471     }
01472   }
01473
01474   for(auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01475     mim_bndy_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)] =
01476       prem_apps_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)];
01477   }
01478
01479   #if MTK_VERBOSE_LEVEL > 4
01480   std::cout << "Collection of mimetic approximations:" << std::endl;
01481   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
```

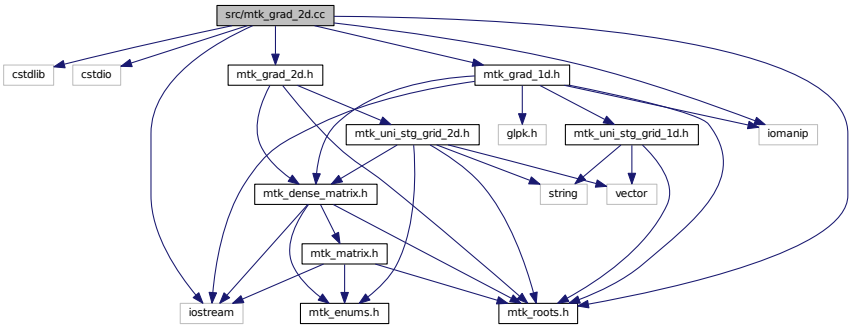
```
01482     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01483       std::cout << std::setw(13) << mim_bndy_[ii*num_bndy_approxs_ + jj];
01484     }
01485     std::cout << std::endl;
01486   }
01487   std::cout << std::endl;
01488   #endif
01489
01490   delete[] lambda;
01491   lambda = nullptr;
01492
01493   delete[] alpha;
01494   alpha = nullptr;
01495
01496   return true;
01497 }
01498
01499 bool mtk::Grad1D::AssembleOperator(void) {
01500
01501   // The output array will have this form:
01502   // 1. The first entry of the array will contain the used order kk.
01503   // 2. The second entry of the array will contain the collection of
01504   // approximating coefficients for the interior of the grid.
01505   // 3. The third entry will contain a collection of weights.
01506   // 4. The next dim_null - 1 entries will contain the collections of
01507   // approximating coefficients for the west boundary of the grid.
01508
01509   gradient_length_ = 1 + order_accuracy_ + order_accuracy_ +
01510     num_bndy_approxs_*num_bndy_coeffs_;
01511
01512   #if MTK_VERBOSE_LEVEL > 2
01513   std::cout << "gradient_length_ = " << gradient_length_ << std::endl;
01514   #endif
01515
01516   try {
01517     gradient_ = new mtk::Real[gradient_length_];
01518   } catch (std::bad_alloc &memory_allocation_exception) {
01519     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01520       std::endl;
01521     std::cerr << memory_allocation_exception.what() << std::endl;
01522   }
01523   memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01524
01526
01527   gradient_[0] = order_accuracy_;
01528
01531
01532   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01533     gradient_[ii + 1] = coeffs_interior_[ii];
01534   }
01535
01537
01538   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01539     gradient_[(order_accuracy_ + 1) + ii] = weights_cbs_[ii];
01540   }
01541
01544
01545   int offset{2*order_accuracy_ + 1};
01546
01547   int aux {}; // Auxiliary variable.
01548
01549   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01550     for (auto ii = 0; ii < num_bndy_approxs_ ; ii++) {
01551       for (auto jj = 0; jj < num_bndy_coeffs_; jj++) {
01552         gradient_[offset + aux] = mim_bndy_[jj*num_bndy_approxs_ + ii];
01553         aux++;
01554       }
01555     }
01556   } else {
01557     gradient_[offset + 0] = prem_apps_[0];
01558     gradient_[offset + 1] = prem_apps_[1];
01559     gradient_[offset + 2] = prem_apps_[2];
01560   }
01561
01562   #if MTK_VERBOSE_LEVEL > 1
01563   std::cout << "1D " << order_accuracy_ << "-order grad built!" << std::endl;
01564   std::cout << std::endl;
01565   #endif
01566
01567   return true;
01568 }
```

## 17.81 src/mtk_grad_2d.cc File Reference

Implements the class Grad2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_grad_1d.h"
#include "mtk_grad_2d.h"
```

Include dependency graph for mtk_grad_2d.cc:




### 17.81.1 Detailed Description

This class implements a 2D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (C↩ BSA).

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Definition in file mtk_grad_2d.cc.

## 17.82 mtk_grad_2d.cc

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
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00022 should be developed and included in any deliverable.
00023
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00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
```

```
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_2d.h"
00066
00067 mtk::Grad2D::Grad2D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Grad2D::Grad2D(const Grad2D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad2D::~Grad2D() {}
00076
00077 bool mtk::Grad2D::ConstructGrad2D(const
      mtk::UniStgGrid2D &grid,
00078                                   int order_accuracy,
00079                                   mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083
00084   int mx = num_cells_x + 1;  // Gx vertical dimension
00085   int nx = num_cells_x + 2;  // Gx horizontal dimension
00086   int my = num_cells_y + 1;  // Gy vertical dimension
00087   int ny = num_cells_y + 2;  // Gy horizontal dimension
00088
00089   mtk::Grad1D grad;
00090
00091   bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00092
00093   #ifdef MTK_PERFORM_PREVENTIONS
00094   if (!info) {
00095     std::cerr << "Mimetic grad could not be built." << std::endl;
00096     return info;
00097   }
00098   #endif
00099
00100   auto west = grid.west_bndy();
00101   auto east = grid.east_bndy();
00102   auto south = grid.south_bndy();
00103   auto north = grid.east_bndy();
00104
00105   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00106   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
```

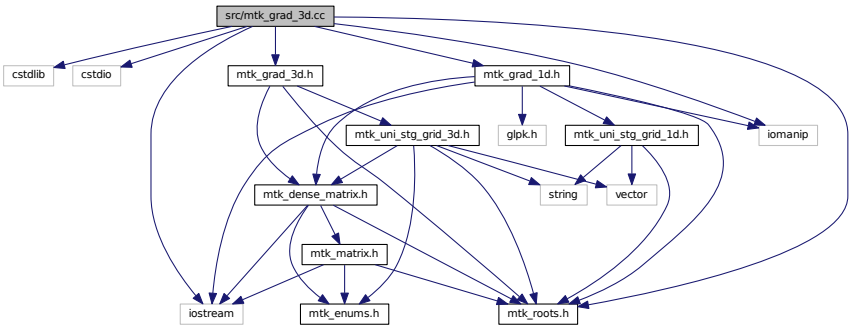
```
00107
00108   mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));
00109   mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00110
00111   bool padded{true};
00112   bool transpose{true};
00113
00114   mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00115   mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00116
00117   mtk::DenseMatrix gxy(mtk::DenseMatrix::Kron(tiy, Gx));
00118   mtk::DenseMatrix gyx(mtk::DenseMatrix::Kron(Gy, tix));
00119
00120   #if MTK_VERBOSE_LEVEL > 2
00121   std::cout << "Gx: " << mx << " by " << nx << std::endl;
00122   std::cout << "Transpose Iy: " << num_cells_y << " by " << ny  << std::endl;
00123   std::cout << "Gy: " << my << " by " << ny << std::endl;
00124   std::cout << "Transpose Ix: " << num_cells_x << " by " << nx  << std::endl;
00125   std::cout << "Grad 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00126     nx*ny <<std::endl;
00127   #endif
00128
00129   mtk::DenseMatrix g2d(mx*num_cells_y + my*num_cells_x, nx*ny);
00130
00131   for(auto ii = 0; ii < nx*ny; ii++) {
00132     for(auto jj = 0; jj < mx*num_cells_y; jj++) {
00133       g2d.SetValue(jj,ii, gxy.GetValue(jj,ii));
00134     }
00135     for(auto kk = 0; kk < my*num_cells_x; kk++) {
00136       g2d.SetValue(kk + mx*num_cells_y, ii, gyx.GetValue(kk,ii));
00137     }
00138   }
00139
00140   gradient_ = g2d;
00141
00142   return info;
00143 }
00144
00145 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix() const {
00146
00147   return gradient_;
00148 }
```

## 17.83 src/mtk_grad_3d.cc File Reference

Implements the class Grad3D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_grad_1d.h"
#include "mtk_grad_3d.h"
```

Include dependency graph for mtk_grad_3d.cc:




### 17.83.1 Detailed Description

This class implements a 3D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (C↩ BSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_3d.cc.

## 17.84 mtk_grad_3d.cc

```
00001
00011 /*
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00013 University. All rights reserved.
00014
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
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00033 be given to the copyright holders.
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```
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_3d.h"
00066
00067 mtk::Grad3D::Grad3D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Grad3D::Grad3D(const Grad3D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad3D::~Grad3D() {}
00076
00077 bool mtk::Grad3D::ConstructGrad3D(const
      mtk::UniStgGrid3D &grid,
00078                                   int order_accuracy,
00079                                   mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083   int num_cells_z = grid.num_cells_z();
00084
00085   int mx = num_cells_x + 1;  // Gx vertical dimension.
00086   int nx = num_cells_x + 2;  // Gx horizontal dimension.
00087   int my = num_cells_y + 1;  // Gy vertical dimension.
00088   int ny = num_cells_y + 2;  // Gy horizontal dimension.
00089   int mz = num_cells_z + 1;  // Gz vertical dimension.
00090   int nz = num_cells_z + 2;  // Gz horizontal dimension.
00091
00092   mtk::Grad1D grad;
00093
00094   bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00095
00096   #ifdef MTK_PERFORM_PREVENTIONS
00097   if (!info) {
00098     std::cerr << "Mimetic grad could not be built." << std::endl;
00099     return info;
00100   }
00101   #endif
00102
00103   auto west = grid.west_bndy();
00104   auto east = grid.east_bndy();
00105   auto south = grid.south_bndy();
00106   auto north = grid.east_bndy();
00107   auto bottom = grid.bottom_bndy();
00108   auto top = grid.top_bndy();
00109
00110   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00111   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00112   mtk::UniStgGrid1D grid_z(bottom, top, num_cells_z);
00113
00114   mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));
00115   mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00116   mtk::DenseMatrix Gz(grad.ReturnAsDenseMatrix(grid_z));
00117
00118   bool padded{true};
00119   bool transpose{true};
00120
00121   mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00122   mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
```

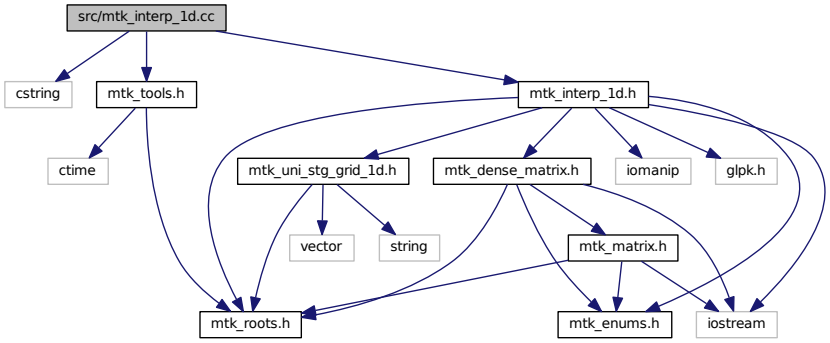
```
00123   mtk::DenseMatrix tiz(num_cells_z, padded, transpose);
00124
00126
00127   mtk::DenseMatrix aux1(mtk::DenseMatrix::Kron(tiz, tiy));
00128   mtk::DenseMatrix gx(mtk::DenseMatrix::Kron(aux1, Gx));
00129
00131
00132   mtk::DenseMatrix aux2(mtk::DenseMatrix::Kron(tiz, Gy));
00133   mtk::DenseMatrix gy(mtk::DenseMatrix::Kron(aux2, tix));
00134
00136
00137   mtk::DenseMatrix aux3(mtk::DenseMatrix::Kron(Gz, tiy));
00138   mtk::DenseMatrix gz(mtk::DenseMatrix::Kron(aux3, tix));
00139
00140   #if MTK_VERBOSE_LEVEL > 2
00141   std::cout << "Gx: " << mx << " by " << nx << std::endl;
00142   std::cout << "Transpose Ix: " << num_cells_x << " by " << nx  << std::endl;
00143   std::cout << "Gy: " << my << " by " << ny << std::endl;
00144   std::cout << "Transpose Iy: " << num_cells_y << " by " << ny  << std::endl;
00145   std::cout << "Gz: " << mz << " by " << nz << std::endl;
00146   std::cout << "Transpose Iz: " << num_cells_z << " by " << nz  << std::endl;
00147   #endif
00148
00150
00151   int total_rows{mx*num_cells_y*num_cells_z +
00152                  num_cells_x*my*num_cells_z +
00153                  num_cells_x*num_cells_y*mz};
00154   int total_cols{nx*ny*nz};
00155
00156   #if MTK_VERBOSE_LEVEL > 2
00157   std::cout << "Grad 3D: " << total_rows << " by " << total_cols << std::endl;
00158   #endif
00159
00160   mtk::DenseMatrix g3d(total_rows, total_cols);
00161
00162   for(auto ii = 0; ii < nx*ny*nz; ii++) {
00163     for(auto jj = 0; jj < mx*num_cells_y*num_cells_z; jj++) {
00164       g3d.SetValue(jj,ii, gx.GetValue(jj,ii));
00165     }
00166
00167     int offset = mx*num_cells_y*num_cells_z;
00168
00169     for(auto kk = 0; kk < num_cells_x*my*num_cells_z; kk++) {
00170       g3d.SetValue(kk + offset, ii, gy.GetValue(kk,ii));
00171     }
00172
00173     offset += num_cells_x*my*num_cells_z;
00174
00175     for(auto ll = 0; ll < num_cells_x*num_cells_y*mz; ll++) {
00176       g3d.SetValue(ll + offset, ii, gz.GetValue(ll,ii));
00177     }
00178   }
00179
00180   gradient_ = g3d;
00181
00182   return info;
00183 }
00184
00185 mtk::DenseMatrix mtk::Grad3D::ReturnAsDenseMatrix() const {
00186
00187   return gradient_;
00188 }
```

## 17.85 src/mtk_interp_1d.cc File Reference

Includes the implementation of the class Interp1D.

```
#include <cstring>
#include "mtk_tools.h"
#include "mtk_interp_1d.h"
```

Include dependency graph for mtk_interp_1d.cc:




## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

## Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::Interp1D &in)

### 17.85.1 Detailed Description

This class implements a 1D interpolation operator.

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu
: Johnny Corbino - jcorbino at mail dot sdsu dot edu

Definition in file mtk_interp_1d.cc.

## 17.86 mtk_interp_1d.cc

```
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00012 /*
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00015
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00017 are permitted provided that the following conditions are met:
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
```

```
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #include <cstring>
00059
00060 #include "mtk_tools.h"
00061
00062 #include "mtk_interp_1d.h"
00063
00064 namespace mtk {
00065
00066 std::ostream& operator <<(std::ostream &stream, mtk::Interp1D &in) {
00067
00069
00070   stream << "coeffs_interior_[1:" << in.order_accuracy_ << "] = ";
00071   for (auto ii = 0; ii < in.order_accuracy_; ++ii) {
00072     stream << std::setw(9) << in.coeffs_interior_[ii] << " ";
00073   }
00074   stream << std::endl;
00075
00076   return stream;
00077 }
00078 }
00079
00080 mtk::Interp1D::Interp1D():
00081   dir_interp_(mtk::SCALAR_TO_VECTOR),
00082   order_accuracy_(mtk::kDefaultOrderAccuracy),
00083   coeffs_interior_(nullptr) {}
00084
00085 mtk::Interp1D::Interp1D(const Interp1D &interp):
00086   dir_interp_(interp.dir_interp_),
00087   order_accuracy_(interp.order_accuracy_),
00088   coeffs_interior_(interp.coeffs_interior_) {}
00089
00090 mtk::Interp1D::~Interp1D() {
00091
00092   delete[] coeffs_interior_;
00093   coeffs_interior_ = nullptr;
00094 }
00095
00096 bool mtk::Interp1D::ConstructInterp1D(int order_accuracy,
      mtk::DirInterp dir) {
00097
00098   #if MTK_PERFORM_PREVENTIONS
00099   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00100   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00101   mtk::Tools::Prevent(dir < mtk::SCALAR_TO_VECTOR &&
00102                       dir > mtk::VECTOR_TO_SCALAR,
00103                       __FILE__, __LINE__, __func__);
00104   #endif
00105
00106   #if MTK_VERBOSE_LEVEL > 2
```

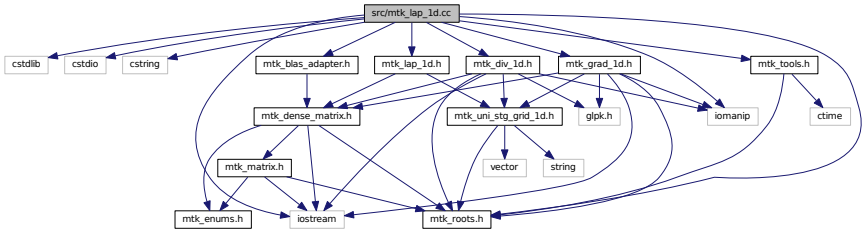
```
00107   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00108   #endif
00109
00110   order_accuracy_ = order_accuracy;
00111
00113
00114   try {
00115     coeffs_interior_ = new mtk::Real[order_accuracy_];
00116   } catch (std::bad_alloc &memory_allocation_exception) {
00117     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00118       std::endl;
00119     std::cerr << memory_allocation_exception.what() << std::endl;
00120   }
00121   memset(coeffs_interior_,
00122          mtk::kZero,
00123          sizeof(coeffs_interior_[0])*order_accuracy_);
00124
00125   for (int ii = 0; ii < order_accuracy_; ++ii) {
00126     coeffs_interior_[ii] = mtk::kOne;
00127   }
00128
00129   return true;
00130 }
00131
00132 mtk::Real *mtk::Interp1D::coeffs_interior() const {
00133
00134   return coeffs_interior_;
00135 }
00136
00137 mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix(
00138   const UniStgGrid1D &grid) const {
00139
00140   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00141
00142   #if MTK_PERFORM_PREVENTIONS
00143   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00144   #endif
00145
00146   int gg_num_rows{};  // Number of rows.
00147   int gg_num_cols{};  // Number of columns.
00148
00149   if (dir_interp_ == mtk::SCALAR_TO_VECTOR) {
00150     gg_num_rows = nn + 1;
00151     gg_num_cols = nn + 2;
00152   } else {
00153     gg_num_rows = nn + 2;
00154     gg_num_cols = nn + 1;
00155   }
00156
00157   // Output matrix featuring sizes for gradient operators.
00158
00159   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00160
00162
00163   out.SetValue(0, 0, mtk::kOne);
00164
00166
00167   for (auto ii = 1; ii < gg_num_rows - 1; ++ii) {
00168     for(auto jj = ii ; jj < order_accuracy_ + ii; ++jj) {
00169       out.SetValue(ii, jj, mtk::kOne/order_accuracy_);
00170     }
00171   }
00172
00174
00175   out.SetValue(gg_num_rows - 1, gg_num_cols - 1, mtk::kOne);
00176
00177   return out;
00178 }
```

## 17.87 src/mtk_lap_1d.cc File Reference

Includes the implementation of the class Lap1D.

```
#include <cstdlib>
#include <cstdio>
#include <cstring>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
```

Include dependency graph for mtk_lap_1d.cc:




## Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

## Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::Lap1D &in)

### 17.87.1 Detailed Description

This class implements a 1D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_1d.cc.

## 17.88 mtk_lap_1d.cc

```
00001
00011 /*
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00014
```

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059 #include <cstring>
00060
00061 #include <iostream>
00062 #include <iomanip>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_tools.h"
00066 #include "mtk_blas_adapter.h"
00067 #include "mtk_grad_1d.h"
00068 #include "mtk_div_1d.h"
00069 #include "mtk_lap_1d.h"
00070
00071 namespace mtk {
00072
00073 std::ostream& operator <<(std::ostream &stream, mtk::Lap1D &in) {
00074
00076
00077   stream << "laplacian_[0] = " << in.laplacian_[0] << std::endl << std::endl;
00078
00080
00081   stream << "laplacian_[1:" << 2*in.order_accuracy_ - 1 << "] = " <<
00082     std::endl << std::endl;
00083   for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00084     stream << std::setw(13) << in.laplacian_[ii] << " ";
00085   }
00086   stream << std::endl << std::endl;
00087
00089
00090   auto offset = 1 + (2*in.order_accuracy_ - 1);
00091
00092   stream << "laplacian_[" << offset << ":" << offset +
00093     (in.order_accuracy_ - 1)*(2*in.order_accuracy_) - 1 << "] = " <<
00094     std::endl << std::endl;
00095
00096   for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00097     for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00098       stream << std::setw(13) <<
```

```
00099         in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00100     }
00101     stream << std::endl;
00102   }
00103
00104   return stream;
00105 }
00106 }
00107
00108 mtk::Lap1D::Lap1D():
00109   order_accuracy_(mtk::kDefaultOrderAccuracy),
00110   laplacian_length_(),
00111   delta_(mtk::kZero),
00112   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00113
00114 mtk::Lap1D::~Lap1D() {
00115
00116   delete [] laplacian_;
00117   laplacian_ = nullptr;
00118 }
00119
00120 int mtk::Lap1D::order_accuracy() const {
00121
00122   return order_accuracy_;
00123 }
00124
00125 mtk::Real mtk::Lap1D::mimetic_threshold() const {
00126
00127   return mimetic_threshold_;
00128 }
00129
00130 mtk::Real mtk::Lap1D::delta() const {
00131
00132   return delta_;
00133 }
00134
00135 bool mtk::Lap1D::ConstructLap1D(int order_accuracy,
00136                                 mtk::Real mimetic_threshold) {
00137
00138   #ifdef MTK_PERFORM_PREVENTIONS
00139   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00140   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00141   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00142                       __FILE__, __LINE__, __func__);
00143
00144   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00145     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00146   }
00147
00148   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00149   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00150   #endif
00151
00152   order_accuracy_ = order_accuracy;
00153   mimetic_threshold_ = mimetic_threshold;
00154
00156   mtk::Grad1D grad; // Mimetic gradient.
00157
00158   bool info = grad.ConstructGrad1D(order_accuracy_, mimetic_threshold_);
00159
00160   #ifdef MTK_PERFORM_PREVENTIONS
00161   if (!info) {
00162     std::cerr << "Mimetic grad could not be built." << std::endl;
00163     return false;
00164   }
00165   #endif
00166
00168
00169   mtk::Div1D div; // Mimetic divergence.
00170
00171   info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00172
00173   #ifdef MTK_PERFORM_PREVENTIONS
00174   if (!info) {
00175     std::cerr << "Mimetic div could not be built." << std::endl;
00176     return false;
00177   }
00178   #endif
00179
00181
00182   // Since these are mimetic operator, we must multiply the matrices arising
```

```
00183   // from both the divergence and the Laplacian, in order to get the
00184   // approximating coefficients for the Laplacian operator.
00185
00186   // However, we must choose a grid that implied a step size of 1, so to get
00187   // the approximating coefficients, without being affected from the
00188   // normalization with respect to the grid (dimensionless).
00189
00190   // Also, the grid must be of the minimum size to support the requested order
00191   // of accuracy. We must please the divergence for this!
00192
00193   mtk::UniStgGrid1D aux(mtk::kZero,
00194                         (mtk::Real) 3*order_accuracy_ - 1,
00195                         3*order_accuracy_ - 1);
00196
00197   #if MTK_VERBOSE_LEVEL > 2
00198   std::cout << "aux =" << std::endl;
00199   std::cout << aux << std::endl;
00200   std::cout <<"aux.delta_x() = " << aux.delta_x() << std::endl;
00201   std::cout << std::endl;
00202   #endif
00203
00204   mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00205
00206   #if MTK_VERBOSE_LEVEL > 4
00207   std::cout << "grad_m =" << std::endl;
00208   std::cout << grad_m << std::endl;
00209   #endif
00210
00211   mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00212
00213   #if MTK_VERBOSE_LEVEL > 4
00214   std::cout << "div_m =" << std::endl;
00215   std::cout << div_m << std::endl;
00216   #endif
00217
00221
00222   mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00223
00224   lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00225
00226   #if MTK_VERBOSE_LEVEL > 4
00227   std::cout << "lap =" << std::endl;
00228   std::cout << lap << std::endl;
00229   #endif
00230
00232
00234
00235   // The output array will have this form:
00236   // 1. The first entry of the array will contain the used order kk.
00237   // 2. The second entry of the array will contain the collection of
00238   // approximating coefficients for the interior of the grid.
00239   // 3. The next entries will contain the collections of approximating
00240   // coefficients for the west boundary of the grid.
00241
00242   laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00243     (order_accuracy_ - 1)*(2*order_accuracy_);
00244
00245   #if MTK_VERBOSE_LEVEL > 2
00246   std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00247   std::cout << std::endl;
00248   #endif
00249
00250   try {
00251     laplacian_ = new mtk::Real[laplacian_length_];
00252   } catch (std::bad_alloc &memory_allocation_exception) {
00253     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00254       std::endl;
00255     std::cerr << memory_allocation_exception.what() << std::endl;
00256   }
00257   memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00258
00260
00261   laplacian_[0] = order_accuracy_;
00262
00265
00266   for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00267     laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00268   }
00269
00271
00272   auto offset = 1 + (2*order_accuracy_ - 1);
```

```
00273
00274   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00275     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00276       laplacian_[offset + ii*(2*order_accuracy_) + jj] =
00277         lap.GetValue(1 + ii,jj);
00278     }
00279   }
00280
00281   delta_ = mtk::kZero;
00282
00283   return true;
00284 }
00285
00286 mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix(
00287   const UniStgGrid1D &grid) const {
00288
00289   int nn{grid.num_cells_x()};  // Number of cells on the grid.
00290
00291   #ifdef MTK_PERFORM_PREVENTIONS
00292   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00293   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00294   #endif
00295
00296   mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00297
00298   delta_ = grid.delta_x();
00299
00300   mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
       dx^2.
00301
00303
00304   auto offset = (1 + 2*order_accuracy_ - 1);
00305
00306   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00307     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00308       lap.SetValue(1 + ii,
00309                    jj,
00310                    idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00311     }
00312   }
00313
00315
00316   offset = 1 + (order_accuracy_ - 1);
00317
00318   int kk{1};
00319   for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00320     int mm{1};
00321     for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00322       lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00323       mm = mm + 1;
00324     }
00325     kk = kk + 1;
00326   }
00327
00329
00330   offset = (1 + 2*order_accuracy_ - 1);
00331
00332   auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00333
00334   auto ll = 1;
00335   auto rr = 1;
00336   for (auto ii = nn; ii > aux - 1; --ii) {
00337     auto cc = 0;
00338     for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00339       lap.SetValue(ii, jj, lap.GetValue(rr,cc));
00340       ++ll;
00341       ++cc;
00342     }
00343     rr++;
00344   }
00345
00352
00353   return lap;
00354 }
00355
00356 const mtk::Real* mtk::Lap1D::data(const UniStgGrid1D &grid) const {
00357
00358   mtk::DenseMatrix tmp;
00359
00360   tmp = ReturnAsDenseMatrix(grid);
00361
```

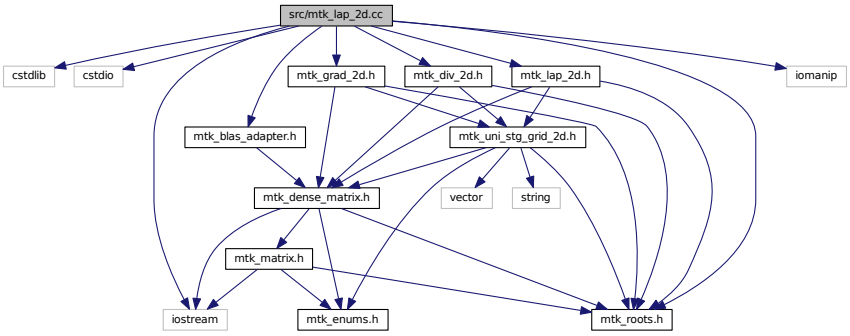
```
00362   return tmp.data();
00363 }
```

## 17.89 src/mtk_lap_2d.cc File Reference

Includes the implementation of the class Lap2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_2d.h"
#include "mtk_div_2d.h"
#include "mtk_lap_2d.h"
```

Include dependency graph for mtk_lap_2d.cc:




### 17.89.1 Detailed Description

This class implements a 2D Laplacian operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (CBSA).

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_2d.cc.

## 17.90 mtk_lap_2d.cc

```
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00011 /*
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00013 University. All rights reserved.
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00017
```

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_blas_adapter.h"
00065 #include "mtk_grad_2d.h"
00066 #include "mtk_div_2d.h"
00067 #include "mtk_lap_2d.h"
00068
00069 mtk::Lap2D::Lap2D(): order_accuracy_(), mimetic_threshold_() {}
00070
00071 mtk::Lap2D::Lap2D(const Lap2D &lap):
00072   order_accuracy_(lap.order_accuracy_),
00073   mimetic_threshold_(lap.mimetic_threshold_) {}
00074
00075 mtk::Lap2D::~Lap2D() {}
00076
00077 bool mtk::Lap2D::ConstructLap2D(const
      mtk::UniStgGrid2D &grid,
00078                                 int order_accuracy,
00079                                 mtk::Real mimetic_threshold) {
00080
00081   mtk::Grad2D gg;
00082   mtk::Div2D dd;
00083
00084   bool info{gg.ConstructGrad2D(grid, order_accuracy, mimetic_threshold)};
00085
00086   #ifdef MTK_PERFORM_PREVENTIONS
00087   if (!info) {
00088     std::cerr << "Mimetic lap could not be built." << std::endl;
00089     return info;
00090   }
00091   #endif
00092
00093   info = dd.ConstructDiv2D(grid, order_accuracy, mimetic_threshold);
00094
00095   #ifdef MTK_PERFORM_PREVENTIONS
00096   if (!info) {
00097     std::cerr << "Mimetic div could not be built." << std::endl;
```

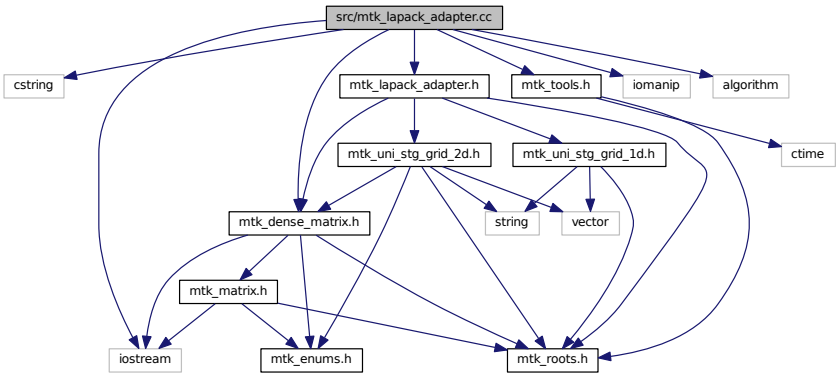
```
00098     return info;
00099   }
00100   #endif
00101
00102   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00103   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00104
00105   laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00106
00107   return info;
00108 }
00109
00110 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix() const {
00111
00112   return laplacian_;
00113 }
00114
00115 mtk::Real *mtk::Lap2D::data() const {
00116
00117   return laplacian_.data();
00118 }
```

## 17.91 src/mtk_lapack_adapter.cc File Reference

Adapter class for the LAPACK API.

```
#include <cstring>
#include <iostream>
#include <iomanip>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_dense_matrix.h"
#include "mtk_lapack_adapter.h"
```

Include dependency graph for mtk_lapack_adapter.cc:




### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Functions

- void mtk::sgesv_ (int *n, int *nrhs, Real *a, int *lda, int *ipiv, Real *b, int *ldb, int *info)
- void mtk::sgels_ (char *trans, int *m, int *n, int *nrhs, Real *a, int *lda, Real *b, int *ldb, Real *work, int *lwork, int *info)

  *Single-precision GEneral matrix Least Squares solver.*
- void mtk::sgeqrf_ (int *m, int *n, Real *a, int *lda, Real *tau, Real *work, int *lwork, int *info)

  *Single-precision GEneral matrix QR Factorization.*
- void mtk::sormqr_ (char *side, char *trans, int *m, int *n, int *k, Real *a, int *lda, Real *tau, Real *c, int *ldc, Real *work, int *lwork, int *info)

  *Single-precision Orthogonal Matrix from QR factorization.*

#### 17.91.1 Detailed Description

This class contains a collection of static classes, that posses direct access to the underlying structure of the matrices, thus allowing programmers to exploit some of the numerical methods implemented in the LAPACK.

The **LAPACK (Linear Algebra PACKage)** is written in Fortran 90 and provides routines for solving systems of simultaneous linear equations, least-squares solutions of linear systems of equations, eigenvalue problems, and singular value problems.

**See also**

http://www.netlib.org/lapack/

**Todo** Write documentation using LaTeX.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lapack_adapter.cc.

## 17.92 mtk_lapack_adapter.cc

```
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00030 completed, unless these modifications are made through the project's GitHub
00031 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00032 should be developed and included in any deliverable.
00033
00034 2. Redistributions of source code must be done through direct
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00063 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00064 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00065 */
00066
00067 #include <cstring>
00068
00069 #include <iostream>
00070 #include <iomanip>
00071
00072 #include <algorithm>
00073
00074 #include "mtk_tools.h"
00075 #include "mtk_dense_matrix.h"
00076 #include "mtk_lapack_adapter.h"
00077
00078 namespace mtk {
00079
00080 extern "C" {
00081
00082 #ifdef MTK_PRECISION_DOUBLE
00083
00102 void dgesv_(int* n,
00103             int* nrhs,
00104             Real* a,
00105             int* lda,
00106             int* ipiv,
00107             Real* b,
00108             int* ldb,
00109             int* info);
00110 #else
00111
00130 void sgesv_(int* n,
00131             int* nrhs,
00132             Real* a,
00133             int* lda,
00134             int* ipiv,
00135             Real* b,
00136             int* ldb,
00137             int* info);
00138 #endif
00139
00140 #ifdef MTK_PRECISION_DOUBLE
00141
00184 void dgels_(char* trans,
00185             int* m,
00186             int* n,
00187             int* nrhs,
00188             Real* a,
00189             int* lda,
00190             Real* b,
00191             int* ldb,
00192             Real* work,
00193             int* lwork,
00194             int* info);
00195 #else
00196
00239 void sgels_(char* trans,
00240             int* m,
00241             int* n,
00242             int* nrhs,
00243             Real* a,
00244             int* lda,
```

```
00245             Real* b,
00246             int* ldb,
00247             Real* work,
00248             int* lwork,
00249             int* info);
00250 #endif
00251
00252 #ifdef MTK_PRECISION_DOUBLE
00253
00282 void dgeqrf_(int *m,
00283              int *n,
00284              Real *a,
00285              int *lda,
00286              Real *tau,
00287              Real *work,
00288              int *lwork,
00289              int *info);
00290 #else
00291
00320 void sgeqrf_(int *m,
00321              int *n,
00322              Real *a,
00323              int *lda,
00324              Real *tau,
00325              Real *work,
00326              int *lwork,
00327              int *info);
00328 #endif
00329
00330 #ifdef MTK_PRECISION_DOUBLE
00331
00365 void dormqr_(char *side,
00366              char *trans,
00367              int *m,
00368              int *n,
00369              int *k,
00370              Real *a,
00371              int *lda,
00372              Real *tau,
00373              Real *c,
00374              int *ldc,
00375              Real *work,
00376              int *lwork,
00377              int *info);
00378 #else
00379
00413 void sormqr_(char *side,
00414              char *trans,
00415              int *m,
00416              int *n,
00417              int *k,
00418              Real *a,
00419              int *lda,
00420              Real *tau,
00421              Real *c,
00422              int *ldc,
00423              Real *work,
00424              int *lwork,
00425              int *info);
00426 #endif
00427 }
00428 }
00429
00430 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00431                                          mtk::Real *rhs) {
00432
00433   #ifdef MTK_PERFORM_PREVENTIONS
00434   mtk::Tools::Prevent(rhs == nullptr, __FILE__, __LINE__, __func__);
00435   #endif
00436
00437   int *ipiv{};                // Array for pivoting information.
00438   int nrhs{1};                // Number of right-hand sides.
00439   int info{};                 // Status of the solution.
00440   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00441
00442   try {
00443     ipiv = new int[mm_rank];
00444   } catch (std::bad_alloc &memory_allocation_exception) {
00445     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00446       std::endl;
```

```
00447     std::cerr << memory_allocation_exception.what() << std::endl;
00448   }
00449   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00450
00451   int ldbb = mm_rank;
00452   int mm_ld = mm_rank;
00453
00454   #ifdef MTK_PRECISION_DOUBLE
00455   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00456   #else
00457   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00458   #endif
00459
00460   delete [] ipiv;
00461
00462   return info;
00463 }
00464
00465 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00466                                          mtk::DenseMatrix &bb) {
00467
00468   int nrhs{bb.num_rows()};  // Number of right-hand sides.
00469
00470   #ifdef MTK_PERFORM_PREVENTIONS
00471   mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00472   #endif
00473
00474   int *ipiv{};               // Array for pivoting information.
00475   int info{};                // Status of the solution.
00476   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00477
00478   try {
00479     ipiv = new int[mm_rank];
00480   } catch (std::bad_alloc &memory_allocation_exception) {
00481     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00482       std::endl;
00483     std::cerr << memory_allocation_exception.what() << std::endl;
00484   }
00485   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00486
00487   int ldbb = mm_rank;
00488   int mm_ld = mm_rank;
00489
00490   #ifdef MTK_PRECISION_DOUBLE
00491   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00492   #else
00493   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00494   #endif
00495
00496   delete [] ipiv;
00497
00498   // After output, the data in the matrix will be column-major ordered.
00499
00500   bb.SetOrdering(mtk::COL_MAJOR);
00501
00502   #if MTK_VERBOSE_LEVEL > 12
00503   std::cout << "bb_col_maj_ord =" << std::endl;
00504   std::cout << bb << std::endl;
00505   #endif
00506
00507   bb.OrderRowMajor();
00508
00509   #if MTK_VERBOSE_LEVEL > 12
00510   std::cout << "bb_row_maj_ord =" << std::endl;
00511   std::cout << bb << std::endl;
00512   #endif
00513
00514   return info;
00515 }
00516
00517 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00518                                          mtk::UniStgGrid1D &rhs) {
00519
00520   int nrhs{1};  // Number of right-hand sides.
00521
00522   int *ipiv{};               // Array for pivoting information.
00523   int info{};                // Status of the solution.
00524   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00525
```

```
00526   try {
00527     ipiv = new int[mm_rank];
00528   } catch (std::bad_alloc &memory_allocation_exception) {
00529     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00530       std::endl;
00531     std::cerr << memory_allocation_exception.what() << std::endl;
00532   }
00533   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00534
00535   int ldbb = mm_rank;
00536   int mm_ld = mm_rank;
00537
00538   mm.OrderColMajor();
00539
00540   #ifdef MTK_PRECISION_DOUBLE
00541   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00542          rhs.discrete_field(), &ldbb, &info);
00543   #else
00544   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00545          rhs.discrete_field(), &ldbb, &info);
00546   #endif
00547
00548   mm.OrderRowMajor();
00549
00550   delete [] ipiv;
00551
00552   return info;
00553 }
00554
00555 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00556                                          mtk::UniStgGrid2D &rhs) {
00557
00558   int nrhs{1};  // Number of right-hand sides.
00559
00560   int *ipiv{};                // Array for pivoting information.
00561   int info{};                 // Status of the solution.
00562   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00563
00564   try {
00565     ipiv = new int[mm_rank];
00566   } catch (std::bad_alloc &memory_allocation_exception) {
00567     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00568       std::endl;
00569     std::cerr << memory_allocation_exception.what() << std::endl;
00570   }
00571   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00572
00573   int ldbb = mm_rank;
00574   int mm_ld = mm_rank;
00575
00576   mm.OrderColMajor();
00577
00578   #ifdef MTK_PRECISION_DOUBLE
00579   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00580          rhs.discrete_field(), &ldbb, &info);
00581   #else
00582   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00583          rhs.discrete_field(), &ldbb, &info);
00584   #endif
00585
00586   mm.OrderRowMajor();
00587
00588   delete [] ipiv;
00589
00590   return info;
00591 }
00592
00593 mtk::DenseMatrix mtk::LAPACKAdapter::QRFactorDenseMatrix
      (mtk::DenseMatrix &aa) {
00594
00595   mtk::Real *work{}; // Working array.
00596   mtk::Real *tau{};  // Array for the Householder scalars.
00597
00598   // Prepare to factorize: allocate and inquire for the value of lwork.
00599   try {
00600     work = new mtk::Real[1];
00601   } catch (std::bad_alloc &memory_allocation_exception) {
00602     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00603       std::endl;
00604     std::cerr << memory_allocation_exception.what() << std::endl;
```

```
00605   }
00606   memset(work, mtk::kZero, sizeof(aa.data()[0])*1);
00607
00608   int lwork{-1};
00609   int info{};
00610
00611   int aa_num_cols = aa.num_cols();
00612   int aaT_num_rows = aa.num_cols();
00613   int aaT_num_cols = aa.num_rows();
00614
00615   #if MTK_VERBOSE_LEVEL > 12
00616   std::cout << "Input matrix BEFORE QR factorization:" << std::endl;
00617   std::cout << aa << std::endl;
00618   #endif
00619
00620   #ifdef MTK_PRECISION_DOUBLE
00621   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00622           tau,
00623           work, &lwork, &info);
00624   #else
00625   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00626           tau,
00627           work, &lwork, &info);
00628   #endif
00629
00630   if (info == 0) {
00631     lwork = (int) work[0];
00632   } else {
00633     std::cerr << "Could not get value for lwork on line " << __LINE__ - 5 <<
00634       std::endl;
00635     std::cerr << "Exiting..." << std::endl;
00636   }
00637
00638   #if MTK_VERBOSE_LEVEL > 10
00639   std::cout << "lwork = " << std::endl << std::setw(12) << lwork << std::endl
00640     << std::endl;
00641   #endif
00642
00643   delete [] work;
00644   work = nullptr;
00645
00646   // Once we know lwork, we can actually invoke the factorization:
00647   try {
00648     work = new mtk::Real [lwork];
00649   } catch (std::bad_alloc &memory_allocation_exception) {
00650     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00651       std::endl;
00652     std::cerr << memory_allocation_exception.what() << std::endl;
00653   }
00654   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00655
00656   int ltau = std::min(aaT_num_rows,aaT_num_cols);
00657
00658   try {
00659     tau = new mtk::Real [ltau];
00660   } catch (std::bad_alloc &memory_allocation_exception) {
00661     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00662       std::endl;
00663     std::cerr << memory_allocation_exception.what() << std::endl;
00664   }
00665   memset(tau, mtk::kZero, sizeof(0.0)*ltau);
00666
00667   #ifdef MTK_PRECISION_DOUBLE
00668   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00669           tau, work, &lwork, &info);
00670   #else
00671   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00672           tau, work, &lwork, &info);
00673   #endif
00674
00675   #ifdef MTK_PERFORM_PREVENTIONS
00676   if (!info) {
00677     std::cout << "QR factorization completed!" << std::endl << std::endl;
00678   } else {
00679     std::cerr << "Error solving system! info = " << info << std::endl;
00680     std::cerr << "Exiting..." << std::endl;
00681   }
00682   #endif
00683
00684   #if MTK_VERBOSE_LEVEL > 12
00685   std::cout << "Input matrix AFTER QR factorization:" << std::endl;
```

```
00686   std::cout << aa << std::endl;
00687   #endif
00688
00689   // We now generate the real matrix Q with orthonormal columns. This has to
00690   // be done separately since the actual output of dgeqrf_ (AA_) represents
00691   // the orthogonal matrix Q as a product of min(aa_num_rows,aa_num_cols)
00692   // elementary Householder reflectors. Notice that we must re-inquire the new
00693   // value for lwork that is used.
00694
00695   bool padded{false};
00696
00697   bool transpose{false};
00698
00699   mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00700
00701   #if MTK_VERBOSE_LEVEL > 12
00702   std::cout << "Initialized QQ_T: " << std::endl;
00703   std::cout << QQ_ << std::endl;
00704   #endif
00705
00706   // Assemble the QQ_ matrix:
00707   lwork = -1;
00708
00709   delete[] work;
00710   work = nullptr;
00711
00712   try {
00713     work = new mtk::Real[1];
00714   } catch (std::bad_alloc &memory_allocation_exception) {
00715     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00716       std::endl;
00717     std::cerr << memory_allocation_exception.what() <<
00718       std::endl;
00719   }
00720   memset(work, mtk::kZero, sizeof(work[0])*1);
00721
00722   char side_{'L'};
00723   char trans_{'N'};
00724
00725   int aux = QQ_.num_rows();
00726
00727   #ifdef MTK_PRECISION_DOUBLE
00728   dormqr_(&side_, &trans_,
00729           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00730           QQ_.data(), &aux, work, &lwork, &info);
00731   #else
00732   formqr_(&side_, &trans_,
00733           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00734           QQ_.data(), &aux, work, &lwork, &info);
00735   #endif
00736
00737   if (info == 0) {
00738     lwork = (int) work[0];
00739   } else {
00740     std::cerr << "Could not get lwork on line " << __LINE__ - 5 << std::endl;
00741     std::cerr << "Exiting..." << std::endl;
00742   }
00743
00744   #if MTK_VERBOSE_LEVEL > 10
00745   std::cout << "lwork = " << std::endl << std::setw(12) << lwork <<
00746     std::endl << std::endl;
00747   #endif
00748
00749   delete[] work;
00750   work = nullptr;
00751
00752   try {
00753     work = new mtk::Real[lwork];
00754   } catch (std::bad_alloc &memory_allocation_exception) {
00755     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00756       std::endl;
00757     std::cerr << memory_allocation_exception.what() << std::endl;
00758   }
00759   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00760
00761   #ifdef MTK_PRECISION_DOUBLE
00762   dormqr_(&side_, &trans_,
00763           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00764           QQ_.data(), &aux, work, &lwork, &info);
00765   #else
00766   formqr_(&side_, &trans_,
```

```
00767           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00768           QQ_.data(), &aux, work, &lwork, &info);
00769   #endif
00770
00771   #ifdef MTK_PERFORM_PREVENTIONS
00772   if (!info) {
00773     std::cout << "Q matrix successfully assembled!" << std::endl << std::endl;
00774   } else {
00775     std::cerr << "Something went wrong solving system! info = " << info <<
00776       std::endl;
00777     std::cerr << "Exiting..." << std::endl;
00778   }
00779   #endif
00780
00781   delete[] work;
00782   work = nullptr;
00783
00784   delete[] tau;
00785   tau = nullptr;
00786
00787   return QQ_;
00788 }
00789
00790 int mtk::LAPACKAdapter::SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00791                                                     mtk::Real *ob_,
00792                                                     int ob_ld_) {
00793
00794   // We first invoke the solver to query for the value of lwork. For this,
00795   // we must at least allocate enough space to allow access to WORK(1), or
00796   // work[0]:
00797
00798   // If LWORK = -1, then a workspace query is assumed; the routine only
00799   // calculates the optimal size of the WORK array, returns this value as
00800   // the first entry of the WORK array, and no error message related to
00801   // LWORK is issued by XERBLA.
00802
00803   mtk::Real *work{}; // Work array.
00804
00805   try {
00806     work = new mtk::Real[1];
00807   } catch (std::bad_alloc &memory_allocation_exception) {
00808     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00809       std::endl;
00810     std::cerr << memory_allocation_exception.what() << std::endl;
00811   }
00812   memset(work, mtk::kZero, sizeof(work[0])*1);
00813
00814   char trans_{'N'};
00815   int nrhs_{1};
00816   int info{0};
00817   int lwork{-1};
00818
00819   int AA_num_rows_  = aa.num_cols();
00820   int AA_num_cols_  = aa.num_rows();
00821   int AA_ld_ = std::max(1,aa.num_cols());
00822
00823   #ifdef MTK_PRECISION_DOUBLE
00824   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00825          ob_, &ob_ld_,
00826          work, &lwork, &info);
00827   #else
00828   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00829          ob_, &ob_ld_,
00830          work, &lwork, &info);
00831   #endif
00832
00833   if (info == 0) {
00834     lwork = (int) work[0];
00835   } else {
00836     std::cerr << "Could not get value for lwork on line " << __LINE__ - 2 <<
00837       std::endl;
00838     std::cerr << "Exiting..." << std::endl;
00839     return info;
00840   }
00841
00842   #if MTK_VERBOSE_LEVEL > 10
00843   std::cout << "lwork = " << std::endl << std::setw(12)<< lwork <<
00844     std::endl << std::endl;
00845   #endif
00846
```

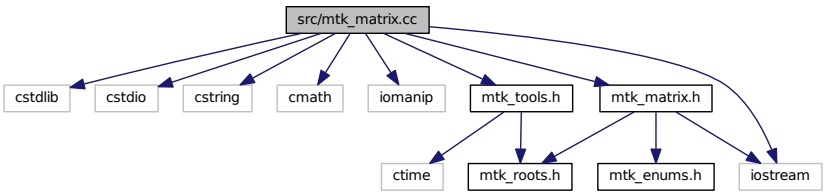
```
00847   // We then use lwork's new value to create the work array:
00848   delete[] work;
00849   work = nullptr;
00850
00851   try {
00852     work = new mtk::Real[lwork];
00853   } catch (std::bad_alloc &memory_allocation_exception) {
00854     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00855     std::cerr << memory_allocation_exception.what() << std::endl;
00856   }
00857   memset(work, 0.0, sizeof(work[0])*lwork);
00858
00859   // We now invoke the solver again:
00860   #ifdef MTK_PRECISION_DOUBLE
00861   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00862          ob_, &ob_ld_,
00863          work, &lwork, &info);
00864   #else
00865   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00866          ob_, &ob_ld_,
00867          work, &lwork, &info);
00868   #endif
00869
00870   delete [] work;
00871   work = nullptr;
00872
00873   return info;
00874 }
```

## 17.93 src/mtk_matrix.cc File Reference

Implementing the representation of a matrix in the MTK.

```
#include <cstdlib>
#include <cstdio>
#include <cstring>
#include <cmath>
#include <iomanip>
#include <iostream>
#include "mtk_tools.h"
#include "mtk_matrix.h"
```

Include dependency graph for mtk_matrix.cc:




### 17.93.1 Detailed Description

Implementation of the representation for the matrices implemented in the MTK.

**Author**

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Definition in file mtk_matrix.cc.

## 17.94 mtk_matrix.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
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00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
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00033
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00040 third parties. The copyright holders disclaim any liability to any recipient for
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00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <cstdlib>
00057 #include <cstdio>
00058 #include <cstring>
00059 #include <cmath>
00060
00061 #include <iomanip>
00062 #include <iostream>
00063
00064 #include "mtk_tools.h"
00065 #include "mtk_matrix.h"
00066
00067 mtk::Matrix::Matrix():
00068   storage_(mtk::DENSE),
00069   ordering_(mtk::ROW_MAJOR),
00070   num_rows_(),
00071   num_cols_(),
00072   num_values_(),
00073   ld_(),
00074   num_zero_(),
00075   num_non_zero_(),
00076   num_null_(),
```

```
00077   num_non_null_(),
00078   kl_(),
00079   ku_(),
00080   bandwidth_(),
00081   abs_density_(),
00082   rel_density_(),
00083   abs_sparsity_(),
00084   rel_sparsity_() {}
00085
00086 mtk::Matrix::Matrix(const Matrix &in):
00087   storage_(in.storage_),
00088   ordering_(in.ordering_),
00089   num_rows_(in.num_rows_),
00090   num_cols_(in.num_cols_),
00091   num_values_(in.num_values_),
00092   ld_(in.ld_),
00093   num_zero_(in.num_zero_),
00094   num_non_zero_(in.num_non_zero_),
00095   num_null_(in.num_null_),
00096   num_non_null_(in.num_non_null_),
00097   kl_(in.kl_),
00098   ku_(in.ku_),
00099   bandwidth_(in.bandwidth_),
00100   abs_density_(in.abs_density_),
00101   rel_density_(in.rel_density_),
00102   abs_sparsity_(in.abs_sparsity_),
00103   rel_sparsity_(in.rel_sparsity_) {}
00104
00105 mtk::Matrix::~Matrix() noexcept {}
00106
00107 mtk::MatrixStorage mtk::Matrix::storage() const noexcept {
00108
00109   return storage_;
00110 }
00111
00112 mtk::MatrixOrdering mtk::Matrix::ordering() const noexcept {
00113
00114   return ordering_;
00115 }
00116
00117 int mtk::Matrix::num_rows() const noexcept {
00118
00119   return num_rows_;
00120 }
00121
00122 int mtk::Matrix::num_cols() const noexcept {
00123
00124   return num_cols_;
00125 }
00126
00127 int mtk::Matrix::num_values() const noexcept {
00128
00129   return num_values_;
00130 }
00131
00132 int mtk::Matrix::ld() const noexcept {
00133
00134   return ld_;
00135 }
00136
00137 int mtk::Matrix::num_zero() const noexcept {
00138
00139   return num_zero_;
00140 }
00141
00142 int mtk::Matrix::num_non_zero() const noexcept {
00143
00144   return num_non_zero_;
00145 }
00146
00147 int mtk::Matrix::num_null() const noexcept {
00148
00149   return num_null_;
00150 }
00151
00152 int mtk::Matrix::num_non_null() const noexcept {
00153
00154   return num_non_null_;
00155 }
00156
00157 int mtk::Matrix::kl() const noexcept {
```

```
00158
00159   return kl_;
00160 }
00161
00162 int mtk::Matrix::ku() const noexcept {
00163
00164   return ku_;
00165 }
00166
00167 int mtk::Matrix::bandwidth() const noexcept {
00168
00169   return bandwidth_;
00170 }
00171
00172 mtk::Real mtk::Matrix::rel_density() const noexcept {
00173
00174   return rel_density_;
00175 }
00176
00177 mtk::Real mtk::Matrix::abs_sparsity() const noexcept {
00178
00179   return abs_sparsity_;
00180 }
00181
00182 mtk::Real mtk::Matrix::rel_sparsity() const noexcept {
00183
00184   return rel_sparsity_;
00185 }
00186
00187 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss)
      noexcept {
00188
00189   #ifdef MTK_PERFORM_PREVENTIONS
00190   mtk::Tools::Prevent(!(ss == mtk::DENSE ||
00191                         ss == mtk::BANDED ||
00192                         ss == mtk::CRS),
00193                       __FILE__, __LINE__, __func__);
00194   #endif
00195
00196   storage_ = ss;
00197 }
00198
00199 void mtk::Matrix::set_ordering(const
      mtk::MatrixOrdering &oo) noexcept {
00200
00201   #ifdef MTK_PERFORM_PREVENTIONS
00202   mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
      mtk::COL_MAJOR),
00203                       __FILE__, __LINE__, __func__);
00204   #endif
00205
00206   ordering_ = oo;
00207
00208   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00209     std::max(1,num_cols_): std::max(1,num_rows_);
00210 }
00211
00212 void mtk::Matrix::set_num_rows(const int &in) noexcept {
00213
00214   #ifdef MTK_PERFORM_PREVENTIONS
00215   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00216   #endif
00217
00218   num_rows_ = in;
00219   num_values_ = num_rows_*num_cols_;
00220   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00221     std::max(1,num_cols_): std::max(1,num_rows_);
00222 }
00223
00224 void mtk::Matrix::set_num_cols(const int &in) noexcept {
00225
00226   #ifdef MTK_PERFORM_PREVENTIONS
00227   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00228   #endif
00229
00230   num_cols_ = in;
00231   num_values_ = num_rows_*num_cols_;
00232   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00233     std::max(1,num_cols_): std::max(1,num_rows_);
00234 }
00235
```

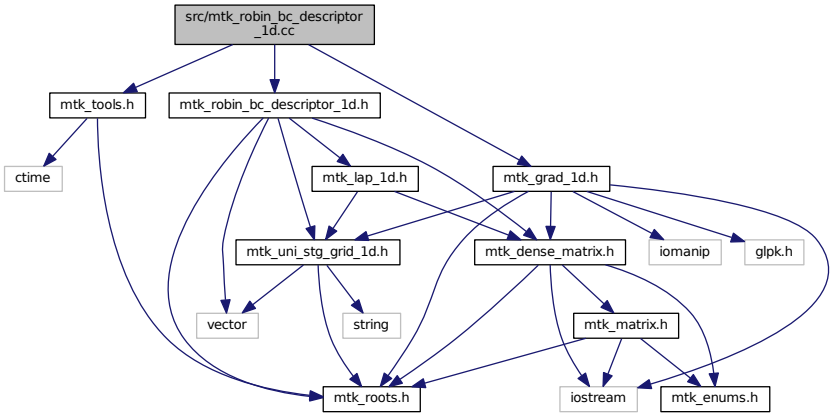
```
00236 void mtk::Matrix::set_num_zero(const int &in) noexcept {
00237
00238   #ifdef MTK_PERFORM_PREVENTIONS
00239   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00240   #endif
00241
00242   num_zero_ = in;
00243   num_non_zero_ = num_values_ - num_zero_;
00244
00246   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00247   rel_sparsity_ = 1.0 - rel_density_;
00248 }
00249
00250 void mtk::Matrix::set_num_null(const int &in) noexcept {
00251
00252   #ifdef MTK_PERFORM_PREVENTIONS
00253   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00254   #endif
00255
00256   num_null_ = in;
00257   num_non_null_ = num_values_ - num_null_;
00258
00260   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00261   abs_sparsity_ = 1.0 - abs_density_;
00262 }
00263
00264 void mtk::Matrix::IncreaseNumZero() noexcept {
00265
00267
00268   num_zero_++;
00269   num_non_zero_ = num_values_ - num_zero_;
00270   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00271   rel_sparsity_ = 1.0 - rel_density_;
00272 }
00273
00274 void mtk::Matrix::IncreaseNumNull() noexcept {
00275
00277
00278   num_null_++;
00279   num_non_null_ = num_values_ - num_null_;
00280   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00281   abs_sparsity_ = 1.0 - abs_density_;
00282 }
```

## 17.95 src/mtk_robin_bc_descriptor_1d.cc File Reference

Impose Robin boundary conditions on the operators and on the grids.

```
#include "mtk_tools.h"
#include "mtk_grad_1d.h"
#include "mtk_robin_bc_descriptor_1d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_1d.cc:




### 17.95.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 1D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

In a 1D context ( $\partial\Omega = \{a,b\} \subset \mathbb{R}$), this condition can be written as follows:

$$\delta_a(a,t)u(a,t) - \eta_a(a,t)u'(a,t) = \beta_a(a,t),$$

$$\delta_b(b,t)u(b,t) + \eta_b(b,t)u'(b,t) = \beta_b(b,t).$$

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the condition in the grids.

**See also**

http://mathworld.wolfram.com/NormalVector.html

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_robin_bc_descriptor_1d.cc.

# 17.96 mtk_robin_bc_descriptor_1d.cc

```
00001
00043 /*
00044 Copyright (C) 2015, Computational Science Research Center, San Diego State
00045 University. All rights reserved.
00046
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00048 are permitted provided that the following conditions are met:
00049
00050 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00060 this list of conditions and the following disclaimer in the documentation and/or
00061 other materials provided with the distribution.
00062
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00080 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #include "mtk_tools.h"
00090 #include "mtk_grad_1d.h"
00091 #include "mtk_robin_bc_descriptor_1d.h"
00092
00093 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D():
00094   highest_order_diff_west_(-1),
00095   highest_order_diff_east_(-1),
00096   west_condition_(nullptr),
00097   east_condition_(nullptr) {}
00098
00099 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D(
00100     const mtk::RobinBCDescriptor1D &desc):
00101   highest_order_diff_west_(desc.highest_order_diff_west_),
00102   highest_order_diff_east_(desc.highest_order_diff_east_),
00103   west_condition_(desc.west_condition_),
00104   east_condition_(desc.east_condition_) {}
00105
00106 mtk::RobinBCDescriptor1D::~RobinBCDescriptor1D() noexcept {}
00107
00108 int mtk::RobinBCDescriptor1D::highest_order_diff_west()
      const noexcept {
00109
00110   return highest_order_diff_west_;
00111 }
00112
00113 int mtk::RobinBCDescriptor1D::highest_order_diff_east()
      const noexcept {
00114
00115   return highest_order_diff_east_;
00116 }
00117
```

```
00118 void mtk::RobinBCDescriptor1D::PushBackWestCoeff(
00119     mtk::CoefficientFunction0D cw) {
00120
00121   #ifdef MTK_PERFORM_PREVENTIONS
00122   mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00123   mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00124                       __FILE__, __LINE__, __func__);
00125   #endif
00126
00127   west_coefficients_.push_back(cw);
00128
00129   highest_order_diff_west_++;
00130 }
00131
00132 void mtk::RobinBCDescriptor1D::PushBackEastCoeff(
00133     mtk::CoefficientFunction0D ce) {
00134
00135   #ifdef MTK_PERFORM_PREVENTIONS
00136   mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00137   mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00138                       __FILE__, __LINE__, __func__);
00139   #endif
00140
00141   east_coefficients_.push_back(ce);
00142
00143   highest_order_diff_east_++;
00144 }
00145
00146 void mtk::RobinBCDescriptor1D::set_west_condition(
00147     mtk::Real (*west_condition)(const mtk::Real &tt)) noexcept {
00148
00149   #ifdef MTK_PERFORM_PREVENTIONS
00150   mtk::Tools::Prevent(west_condition == nullptr, __FILE__, __LINE__, __func__);
00151   #endif
00152
00153   west_condition_ = west_condition;
00154 }
00155
00156 void mtk::RobinBCDescriptor1D::set_east_condition(
00157     mtk::Real (*east_condition)(const mtk::Real &tt)) noexcept {
00158
00159   #ifdef MTK_PERFORM_PREVENTIONS
00160   mtk::Tools::Prevent(east_condition == nullptr, __FILE__, __LINE__, __func__);
00161   #endif
00162
00163   east_condition_ = east_condition;
00164 }
00165
00166 bool mtk::RobinBCDescriptor1D::ImposeOnLaplacianMatrix(
00167     const mtk::Lap1D &lap,
00168     mtk::DenseMatrix &matrix,
00169     const mtk::Real &time) const {
00170
00171   #ifdef MTK_PERFORM_PREVENTIONS
00172   mtk::Tools::Prevent(highest_order_diff_west_ == -1,
00173                       __FILE__, __LINE__, __func__);
00174   mtk::Tools::Prevent(highest_order_diff_east_ == -1,
00175                       __FILE__, __LINE__, __func__);
00176   mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00177   mtk::Tools::Prevent(matrix.num_cols() == 0, __FILE__, __LINE__, __func__);
00178   #endif
00179
00182   matrix.SetValue(0, 0, (west_coefficients_[0])(time));
00183
00185   matrix.SetValue(matrix.num_rows() - 1,
00186                   matrix.num_cols() - 1,
00187                   (east_coefficients_[0])(time));
00188
00190   if (highest_order_diff_west_ > 0) {
00191
00193     mtk::Grad1D grad;
00194     if (!grad.ConstructGrad1D(lap.order_accuracy(),
00195                               lap.mimetic_threshold())) {
00196       return false;
00197     }
00198
00200
00204     mtk::DenseMatrix coeffs(grad.mim_bndy());
00205
00206     mtk::Real idx = mtk::kOne/lap.delta();
00207
```

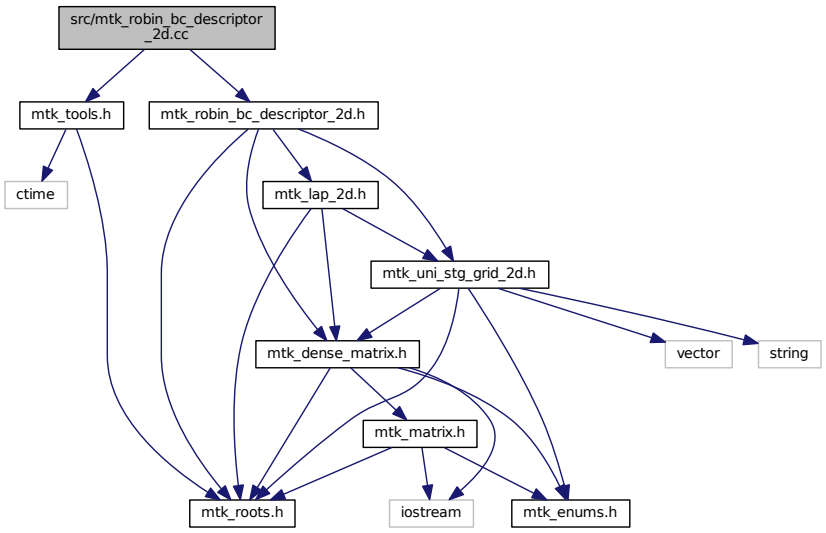
```
00209     for (int ii = 0; ii < coeffs.num_cols(); ++ii) {
00211       mtk::Real aux{idx*coeffs.GetValue(0, ii)};
00214       mtk::Real unit_normal{-mtk::kOne};
00215       aux *= unit_normal*(west_coefficients_[1])(time);
00217       matrix.SetValue(0, ii, matrix.GetValue(0, ii) + aux);
00218     }
00219
00221
00226
00227     for (int ii = 0; ii < coeffs.num_cols(); ++ii) {
00229       mtk::Real aux{idx*coeffs.GetValue(0, ii)};
00233       mtk::Real unit_normal{mtk::kOne};
00234       aux *= -unit_normal*(east_coefficients_[1])(time);
00236       matrix.SetValue(matrix.num_rows() - 1,
00237                       matrix.num_rows() - 1 - ii,
00238                       matrix.GetValue(matrix.num_rows() - 1,
00239                                       matrix.num_rows() - 1 -ii) + aux);
00240     }
00241   }
00242
00243   return true;
00244 }
00245
00246 void mtk::RobinBCDescriptor1D::ImposeOnGrid(
00247     UniStgGrid1D &grid,
00248     const mtk::Real &time) const {
00249
00250   #ifdef MTK_PERFORM_PREVENTIONS
00251   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00252   mtk::Tools::Prevent(west_condition_ == nullptr, __FILE__, __LINE__, __func__);
00253   mtk::Tools::Prevent(east_condition_ == nullptr, __FILE__, __LINE__, __func__);
00254   #endif
00255
00256   (grid.discrete_field())[0] = west_condition_(time);
00257   (grid.discrete_field())[grid.num_cells_x() + 1] = east_condition_(time);
00258 }
```

## 17.97 src/mtk_robin_bc_descriptor_2d.cc File Reference

Impose Robin boundary conditions on the operators and on the grids.

```
#include "mtk_tools.h"
#include "mtk_robin_bc_descriptor_2d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_2d.cc:




### 17.97.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let $u(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ be the solution to an ordinary or partial differential equation of interest. We say that $u$ satisfies a **Robin boundary condition on** $\partial\Omega$ if and only if there exists $\beta(\mathbf{x},t) : \Omega \times [t_0,t_n] \mapsto \mathbb{R}$ so that:

$$\forall t \in [t_0,t_n] \; \forall \mathbf{x} \in \partial\Omega : \delta(\mathbf{x},t)u(\mathbf{x},t) + \eta(\mathbf{x},t)(\hat{\mathbf{n}} \cdot \nabla u) = \beta(\mathbf{x},t).$$

Intuitively, a **Robin boundary condition** is a constraint that must be satisfied by any linear combination of any scalar field $u$ and its first normal derivative, in order for $u$ to represent a unique solution to a given ordinary or partial differential equation of interest.

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

#### See also

http://mathworld.wolfram.com/NormalVector.html

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_robin_bc_descriptor_2d.cc.

## 17.98 mtk_robin_bc_descriptor_2d.cc

```
00001
00034 /*
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00036 University. All rights reserved.
00037
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00039 are permitted provided that the following conditions are met:
00040
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00042 and a copy of the modified files should be reported once modifications are
00043 completed, unless these modifications are made through the project's GitHub
00044 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00045 should be developed and included in any deliverable.
00046
00047 2. Redistributions of source code must be done through direct
00048 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00051 this list of conditions and the following disclaimer in the documentation and/or
00052 other materials provided with the distribution.
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00074 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00075 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00076 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00077 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00078 */
00079
00080 #include "mtk_tools.h"
00081
00082 #include "mtk_robin_bc_descriptor_2d.h"
00083
00084 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D():
00085   highest_order_diff_west_(-1),
00086   highest_order_diff_east_(-1),
00087   highest_order_diff_south_(-1),
00088   highest_order_diff_north_(-1),
00089   west_condition_(),
00090   east_condition_(),
00091   south_condition_(),
00092   north_condition_() {}
00093
00094 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D(
00095     const mtk::RobinBCDescriptor2D &desc):
00096   highest_order_diff_west_(desc.highest_order_diff_west_),
00097   highest_order_diff_east_(desc.highest_order_diff_east_),
00098   highest_order_diff_south_(desc.highest_order_diff_south_),
00099   highest_order_diff_north_(desc.highest_order_diff_north_),
00100   west_condition_(desc.west_condition_),
00101   east_condition_(desc.east_condition_),
00102   south_condition_(desc.south_condition_),
00103   north_condition_(desc.north_condition_) {}
00104
00105 mtk::RobinBCDescriptor2D::~RobinBCDescriptor2D() noexcept {}
00106
00107 int mtk::RobinBCDescriptor2D::highest_order_diff_west()
     const noexcept {
00108
00109   return highest_order_diff_west_;
```

```
00110 }
00111
00112 int mtk::RobinBCDescriptor2D::highest_order_diff_east()
      const noexcept {
00113
00114   return highest_order_diff_east_;
00115 }
00116
00117 int mtk::RobinBCDescriptor2D::highest_order_diff_south()
      const noexcept {
00118
00119   return highest_order_diff_south_;
00120 }
00121
00122 int mtk::RobinBCDescriptor2D::highest_order_diff_north()
      const noexcept {
00123
00124   return highest_order_diff_north_;
00125 }
00126
00127 void mtk::RobinBCDescriptor2D::PushBackWestCoeff(
00128     mtk::CoefficientFunction1D cw) {
00129
00130   #ifdef MTK_PERFORM_PREVENTIONS
00131   mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00132   mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00133                       __FILE__, __LINE__, __func__);
00134   #endif
00135
00136   west_coefficients_.push_back(cw);
00137
00138   highest_order_diff_west_++;
00139 }
00140
00141 void mtk::RobinBCDescriptor2D::PushBackEastCoeff(
00142     mtk::CoefficientFunction1D ce) {
00143
00144   #ifdef MTK_PERFORM_PREVENTIONS
00145   mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00146   mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00147                       __FILE__, __LINE__, __func__);
00148   #endif
00149
00150   east_coefficients_.push_back(ce);
00151
00152   highest_order_diff_east_++;
00153 }
00154
00155 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff(
00156     mtk::CoefficientFunction1D cs) {
00157
00158   #ifdef MTK_PERFORM_PREVENTIONS
00159   mtk::Tools::Prevent(cs == nullptr, __FILE__, __LINE__, __func__);
00160   mtk::Tools::Prevent(highest_order_diff_south_ > 1,
00161                       __FILE__, __LINE__, __func__);
00162   #endif
00163
00164   south_coefficients_.push_back(cs);
00165
00166   highest_order_diff_south_++;
00167 }
00168
00169 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff(
00170     mtk::CoefficientFunction1D cn) {
00171
00172   #ifdef MTK_PERFORM_PREVENTIONS
00173   mtk::Tools::Prevent(cn == nullptr, __FILE__, __LINE__, __func__);
00174   mtk::Tools::Prevent(highest_order_diff_north_ > 1,
00175                       __FILE__, __LINE__, __func__);
00176   #endif
00177
00178   north_coefficients_.push_back(cn);
00179
00180   highest_order_diff_north_++;
00181 }
00182
00183 void mtk::RobinBCDescriptor2D::set_west_condition(
00184     mtk::Real (*west_condition)(const mtk::Real &yy,
00185                                 const mtk::Real &tt)) noexcept {
00186
00187   #ifdef MTK_PERFORM_PREVENTIONS
```

```
00188   mtk::Tools::Prevent(west_condition == nullptr, __FILE__, __LINE__, __func__);
00189   #endif
00190
00191   west_condition_ = west_condition;
00192 }
00193
00194 void mtk::RobinBCDescriptor2D::set_east_condition(
00195     mtk::Real (*east_condition)(const mtk::Real &yy,
00196                                 const mtk::Real &tt)) noexcept {
00197
00198   #ifdef MTK_PERFORM_PREVENTIONS
00199   mtk::Tools::Prevent(east_condition == nullptr, __FILE__, __LINE__, __func__);
00200   #endif
00201
00202   east_condition_ = east_condition;
00203 }
00204
00205 void mtk::RobinBCDescriptor2D::set_south_condition(
00206     mtk::Real (*south_condition)(const mtk::Real &xx,
00207                                  const mtk::Real &tt)) noexcept {
00208
00209   #ifdef MTK_PERFORM_PREVENTIONS
00210   mtk::Tools::Prevent(south_condition == nullptr,
00211                       __FILE__, __LINE__, __func__);
00212   #endif
00213
00214   south_condition_ = south_condition;
00215 }
00216
00217 void mtk::RobinBCDescriptor2D::set_north_condition(
00218     mtk::Real (*north_condition)(const mtk::Real &xx,
00219                                  const mtk::Real &tt)) noexcept {
00220
00221   #ifdef MTK_PERFORM_PREVENTIONS
00222   mtk::Tools::Prevent(north_condition == nullptr,
00223                       __FILE__, __LINE__, __func__);
00224   #endif
00225
00226   north_condition_ = north_condition;
00227 }
00228
00229 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryNoSpace
     (
00230     const mtk::Lap2D &lap,
00231     const mtk::UniStgGrid2D &grid,
00232     mtk::DenseMatrix &matrix,
00233     const mtk::Real &time) const {
00234
00236
00237   // For the south-west corner:
00238   auto cc = (south_coefficients_[0])(grid.west_bndy(), time);
00239
00240   #if MTK_VERBOSE_LEVEL > 2
00241   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00242     matrix.num_cols() << " columns." << std::endl;
00243   std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00244   #endif
00245
00246   matrix.SetValue(0, 0, cc);
00247
00248   // Compute first centers per dimension.
00249   auto first_center_x = grid.west_bndy() + grid.delta_x()/
     mtk::kTwo;
00250
00251   // For each entry on the diagonal (south boundary):
00252   for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00253     // Evaluate next set spatial coordinates to evaluate the coefficient.
00254     mtk::Real xx = first_center_x + ii*grid.delta_x();
00255     // Evaluate and assign the Dirichlet coefficient.
00256     cc = (south_coefficients_[0])(xx, time);
00257
00258     #if MTK_VERBOSE_LEVEL > 2
00259     std::cout << "Setting at " << ii + 1 << ' ' << ii + 1 << std::endl;
00260     #endif
00261
00262     matrix.SetValue(ii + 1, ii + 1, cc);
00263   }
00264
00265   // For the south-east corner:
00266   cc = (south_coefficients_[0])(grid.east_bndy(), time);
00267
```

```
00268   #if MTK_VERBOSE_LEVEL > 2
00269   std::cout << "Setting at " << grid.num_cells_x() + 1 << ' ' <<
00270     grid.num_cells_x() + 1 << std::endl;
00271   #endif
00272
00273   matrix.SetValue(grid.num_cells_x() + 1, grid.num_cells_x() + 1, cc);
00274
00275   if (highest_order_diff_south_ > 0) {
00276
00278   }
00280
00281   return true;
00282 }
00283
00284 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryWithSpace
      (
00285     const mtk::Lap2D &lap,
00286     const mtk::UniStgGrid2D &grid,
00287     mtk::DenseMatrix &matrix,
00288     const mtk::Real &time) const {
00289
00291
00294
00295   // For each entry on the diagonal:
00296   for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00297     // Evaluate next set spatial coordinates to evaluate the coefficient.
00298     mtk::Real xx{(grid.discrete_domain_x())[ii]};
00299     // Evaluate and assign the Dirichlet coefficient.
00300     mtk::Real cc = (south_coefficients_[0])(xx, time);
00301     matrix.SetValue(ii, ii, cc);
00302   }
00303
00304   if (highest_order_diff_south_ > 0) {
00305
00307   }
00308
00309   return true;
00310 }
00311
00312 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryNoSpace
      (
00313     const mtk::Lap2D &lap,
00314     const mtk::UniStgGrid2D &grid,
00315     mtk::DenseMatrix &matrix,
00316     const mtk::Real &time) const {
00317
00318   int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00319
00321
00322   // For the north-west corner:
00323   mtk::Real cc =
00324     (north_coefficients_[0])(grid.west_bndy(), time);
00325
00326   #if MTK_VERBOSE_LEVEL > 2
00327   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00328     matrix.num_cols() << " columns." << std::endl;
00329   std::cout << "Setting at " << north_offset << ' ' << north_offset <<
00330     std::endl;
00331   #endif
00332
00333   matrix.SetValue(north_offset, north_offset, cc);
00334
00335   // Compute first centers per dimension.
00336   auto first_center_x = grid.west_bndy() + grid.delta_x()/
      mtk::kTwo;
00337
00338   // For each entry on the diagonal (north boundary):
00339   for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00340     // Evaluate next set spatial coordinates to evaluate the coefficient.
00341     mtk::Real xx = first_center_x + ii*grid.delta_x();
00342     // Evaluate and assign the Dirichlet coefficient.
00343     cc = (north_coefficients_[0])(xx, time);
00344
00345     #if MTK_VERBOSE_LEVEL > 2
00346     std::cout << "Setting at " << north_offset + ii + 1 << ' ' <<
00347       north_offset + ii + 1 << std::endl;
00348     #endif
00349
00350     matrix.SetValue(north_offset + ii + 1, north_offset + ii + 1, cc);
00351   }
00352
```

```
00353   // For the north-east corner:
00354   cc = (north_coefficients_[0])(grid.east_bndy(), time);
00355
00356   #if MTK_VERBOSE_LEVEL > 2
00357   std::cout << "Setting at " << north_offset + grid.num_cells_x() + 1 <<
00358     ' ' << north_offset + grid.num_cells_x() + 1 << std::endl;
00359   #endif
00360
00361   matrix.SetValue(north_offset + grid.num_cells_x() + 1,
00362                   north_offset + grid.num_cells_x() + 1, cc);
00363
00364   if (highest_order_diff_north_ > 0) {
00365
00367   }
00368
00369   return true;
00370 }
00371
00372 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryWithSpace
      (
00373     const mtk::Lap2D &lap,
00374     const mtk::UniStgGrid2D &grid,
00375     mtk::DenseMatrix &matrix,
00376     const mtk::Real &time) const {
00377
00379
00380   int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00381
00383   for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00385     mtk::Real xx{(grid.discrete_domain_x())[ii]};
00387     mtk::Real cc = (north_coefficients_[0])(xx, time);
00388     matrix.SetValue(north_offset + ii, north_offset + ii, cc);
00389   }
00390
00391   if (highest_order_diff_north_ > 0) {
00392
00394   }
00395
00396   return true;
00397 }
00398
00399 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryNoSpace
      (
00400     const mtk::Lap2D &lap,
00401     const mtk::UniStgGrid2D &grid,
00402     mtk::DenseMatrix &matrix,
00403     const mtk::Real &time) const {
00404
00406
00407   // For the south-west corner:
00408   auto cc = (west_coefficients_[0])(grid.south_bndy(), time);
00409
00410   #if MTK_VERBOSE_LEVEL > 2
00411   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00412     matrix.num_cols() << " columns." << std::endl;
00413   std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00414   #endif
00415
00419
00420   mtk::Real harmonic_mean = mtk::kOne/matrix.GetValue(0, 0) +
      mtk::kOne/cc;
00421   harmonic_mean = mtk::kTwo/harmonic_mean;
00422
00423   matrix.SetValue(0, 0, harmonic_mean);
00424
00425   int west_offset{grid.num_cells_x() + 1};
00426
00427   auto first_center_y = grid.south_bndy() + grid.delta_y()/
      mtk::kTwo;
00428
00429   // For each west entry on the diagonal (west boundary):
00430   for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00431     // Evaluate next set spatial coordinates to evaluate the coefficient.
00432     mtk::Real yy = first_center_y + ii*grid.delta_y();
00433     // Evaluate and assign the Dirichlet coefficient.
00434     cc = (west_coefficients_[0])(yy, time);
00435
00436     #if MTK_VERBOSE_LEVEL > 2
00437     std::cout << "Setting at " << west_offset + ii + 1 << ' ' <<
00438       west_offset + ii + 1 << std::endl;
00439     #endif
```

```
00440
00441     matrix.SetValue(west_offset + ii + 1, west_offset + ii + 1, cc);
00442
00443     west_offset += grid.num_cells_x() + 1;
00444   }
00445
00446   // For the north-west corner:
00447   cc = (west_coefficients_[0])(grid.north_bndy(), time);
00448
00449   west_offset += grid.num_cells_x() + 1;
00450   int aux{west_offset};
00451   #if MTK_VERBOSE_LEVEL > 2
00452   std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00453   #endif
00454
00455   harmonic_mean = mtk::kOne/matrix.GetValue(aux, aux) +
      mtk::kOne/cc;
00456   harmonic_mean = mtk::kTwo/harmonic_mean;
00457
00458   matrix.SetValue(aux, aux, harmonic_mean);
00459
00460   if (highest_order_diff_west_ > 0) {
00461
00463   }
00464
00465   return true;
00466 }
00467
00468 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryWithSpace
      (
00469     const mtk::Lap2D &lap,
00470     const mtk::UniStgGrid2D &grid,
00471     mtk::DenseMatrix &matrix,
00472     const mtk::Real &time) const {
00473
00475
00476   int west_offset{grid.num_cells_x() + 1};
00477   // For each west entry on the diagonal:
00478   for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00479     // Evaluate next set spatial coordinates to evaluate the coefficient.
00480     mtk::Real yy{(grid.discrete_domain_y())[ii]};
00481     // Evaluate and assign the Dirichlet coefficient.
00482     mtk::Real cc = (west_coefficients_[0])(yy, time);
00483     matrix.SetValue(west_offset + ii, west_offset + ii, cc);
00484     west_offset += grid.num_cells_x() + 1;
00485   }
00486
00487   if (highest_order_diff_west_ > 0) {
00488
00490   }
00491
00492   return true;
00493 }
00494
00495 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryNoSpace
      (
00496     const mtk::Lap2D &lap,
00497     const mtk::UniStgGrid2D &grid,
00498     mtk::DenseMatrix &matrix,
00499     const mtk::Real &time) const {
00500
00502
00503   // For the south-east corner:
00504   auto cc = (east_coefficients_[0])(grid.south_bndy(), time);
00505
00506   int east_offset{grid.num_cells_x() + 1};
00507   #if MTK_VERBOSE_LEVEL > 2
00508   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00509     matrix.num_cols() << " columns." << std::endl;
00510   std::cout << "Setting at " << east_offset << ' ' << east_offset <<
00511     std::endl;
00512   #endif
00513
00514   mtk::Real harmonic_mean =
00515     mtk::kOne/matrix.GetValue(east_offset,east_offset) +
      mtk::kOne/cc;
00516   harmonic_mean = mtk::kTwo/harmonic_mean;
00517
00518   matrix.SetValue(east_offset, east_offset, harmonic_mean);
00519
00520   auto first_center_y = grid.south_bndy() + grid.delta_y()/
```

```
    mtk::kTwo;
00521
00522   // For each east entry on the diagonal (east boundary):
00523   for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00524
00525     east_offset += grid.num_cells_x() + 1;
00526
00527     // Evaluate next set spatial coordinates to evaluate the coefficient.
00528     mtk::Real yy = first_center_y + ii*grid.delta_y();
00529     // Evaluate and assign the Dirichlet coefficient.
00530     cc = (east_coefficients_[0])(yy, time);
00531
00532     #if MTK_VERBOSE_LEVEL > 2
00533     std::cout << "Setting at " << east_offset + ii + 1 << ' ' <<
00534       east_offset + ii + 1 << std::endl;
00535     #endif
00536
00537     matrix.SetValue(east_offset + ii + 1, east_offset + ii + 1, cc);
00538   }
00539
00540   // For the north-east corner:
00541   cc = (east_coefficients_[0])(grid.north_bndy(), time);
00542
00543   east_offset += grid.num_cells_x() + 1;
00544   east_offset += grid.num_cells_x() + 1;
00545   int aux{east_offset};
00546   #if MTK_VERBOSE_LEVEL > 2
00547   std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00548   #endif
00549
00550   harmonic_mean =
00551     mtk::kOne/matrix.GetValue(aux, aux) + mtk::kOne/cc;
00552   harmonic_mean = mtk::kTwo/harmonic_mean;
00553
00554   matrix.SetValue(aux, aux, harmonic_mean);
00555
00556   if (highest_order_diff_east_ > 0) {
00557
00559   }
00560
00561   return true;
00562 }
00563
00564 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryWithSpace
     (
00565     const mtk::Lap2D &lap,
00566     const mtk::UniStgGrid2D &grid,
00567     mtk::DenseMatrix &matrix,
00568     const mtk::Real &time) const {
00569
00571
00572   int east_offset{grid.num_cells_x() + 1};
00573   // For each west entry on the diagonal:
00574   for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00575     east_offset += grid.num_cells_x() + 1;
00576     // Evaluate next set spatial coordinates to evaluate the coefficient.
00577     mtk::Real yy{(grid.discrete_domain_y())[ii]};
00578     // Evaluate and assign the arithmetic mean of Dirichlet coefficients.
00579     mtk::Real cc = (east_coefficients_[0])(yy, time);
00580     matrix.SetValue(east_offset + ii, east_offset + ii, cc);
00581   }
00582
00583   if (highest_order_diff_east_ > 0) {
00584
00586   }
00587
00588   return true;
00589 }
00590
00591 bool mtk::RobinBCDescriptor2D::ImposeOnLaplacianMatrix(
00592     const mtk::Lap2D &lap,
00593     const mtk::UniStgGrid2D &grid,
00594     mtk::DenseMatrix &matrix,
00595     const mtk::Real &time) const {
00596
00597   #ifdef MTK_PERFORM_PREVENTIONS
00598   mtk::Tools::Prevent(highest_order_diff_south_ == -1,
00599                       __FILE__, __LINE__, __func__);
00600   mtk::Tools::Prevent(highest_order_diff_north_ == -1,
00601                       __FILE__, __LINE__, __func__);
00602   mtk::Tools::Prevent(highest_order_diff_west_ == -1,
```

```
00603                       __FILE__, __LINE__, __func__);
00604   mtk::Tools::Prevent(highest_order_diff_east_ == -1,
00605                       __FILE__, __LINE__, __func__);
00606   mtk::Tools::Prevent(grid.nature() != mtk::SCALAR,
00607                       __FILE__, __LINE__, __func__);
00608   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00609   mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00610   mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00611   mtk::Tools::Prevent(matrix.num_cols() == 0, __FILE__, __LINE__, __func__);
00612   #endif
00613
00616
00617   bool success{true};
00618
00619   if (!grid.Bound()) {
00620     success = ImposeOnSouthBoundaryNoSpace(lap, grid, matrix, time);
00621     #ifdef MTK_PERFORM_PREVENTIONS
00622     if (!success) {
00623       return false;
00624     }
00625     #endif
00626     success = ImposeOnNorthBoundaryNoSpace(lap, grid, matrix, time);
00627     #ifdef MTK_PERFORM_PREVENTIONS
00628     if (!success) {
00629       return false;
00630     }
00631     #endif
00632     success = ImposeOnWestBoundaryNoSpace(lap, grid, matrix, time);
00633     #ifdef MTK_PERFORM_PREVENTIONS
00634     if (!success) {
00635       return false;
00636     }
00637     #endif
00638     success = ImposeOnEastBoundaryNoSpace(lap, grid, matrix, time);
00639     #ifdef MTK_PERFORM_PREVENTIONS
00640     if (!success) {
00641       return false;
00642     }
00643     #endif
00644   } else {
00645     success = ImposeOnSouthBoundaryWithSpace(lap, grid, matrix, time);
00646     #ifdef MTK_PERFORM_PREVENTIONS
00647     if (!success) {
00648       return false;
00649     }
00650     #endif
00651     success = ImposeOnNorthBoundaryWithSpace(lap, grid, matrix, time);
00652     #ifdef MTK_PERFORM_PREVENTIONS
00653     if (!success) {
00654       return false;
00655     }
00656     #endif
00657     success = ImposeOnWestBoundaryWithSpace(lap, grid, matrix, time);
00658     #ifdef MTK_PERFORM_PREVENTIONS
00659     if (!success) {
00660       return false;
00661     }
00662     #endif
00663     success = ImposeOnEastBoundaryWithSpace(lap, grid, matrix, time);
00664     #ifdef MTK_PERFORM_PREVENTIONS
00665     if (!success) {
00666       return false;
00667     }
00668     #endif
00669   }
00670
00671   return success;
00672 }
00673
00674 void mtk::RobinBCDescriptor2D::ImposeOnGrid(
00675     mtk::UniStgGrid2D &grid,
00676     const mtk::Real &time) const {
00677
00678   #ifdef MTK_PERFORM_PREVENTIONS
00679   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00680   mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00681   mtk::Tools::Prevent(west_condition_ == nullptr, __FILE__, __LINE__, __func__);
00682   mtk::Tools::Prevent(east_condition_ == nullptr, __FILE__, __LINE__, __func__);
00683   mtk::Tools::Prevent(south_condition_ == nullptr,
00684                       __FILE__, __LINE__, __func__);
00685   mtk::Tools::Prevent(north_condition_ == nullptr,
```

```
00686                       __FILE__, __LINE__, __func__);
00687   #endif
00688
00690   if (grid.nature() == mtk::SCALAR) {
00691
00693
00695     mtk::Real xx = grid.west_bndy();
00696     (grid.discrete_field())[0] = south_condition_(xx, time);
00697
00699     xx = xx + grid.delta_x()/mtk::kTwo;
00700     // For every point on the south boundary:
00701     for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00702       (grid.discrete_field())[ii + 1] =
00703         south_condition_(xx + ii*grid.delta_x(), time);
00704     }
00705
00707     xx = grid.east_bndy();
00708     (grid.discrete_field())[grid.num_cells_x() + 1] =
00709       south_condition_(xx, time);
00710
00712
00714     xx = grid.west_bndy();
00715     int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00716     (grid.discrete_field())[north_offset] = north_condition_(xx, time);
00717
00719     xx = xx + grid.delta_x()/mtk::kTwo;
00720     for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00721       (grid.discrete_field())[north_offset + ii + 1] =
00722         north_condition_(xx + ii*grid.delta_x(), time);
00723     }
00724
00726     xx = grid.east_bndy();
00727     (grid.discrete_field())[north_offset + grid.num_cells_x() + 1] =
00728         north_condition_(xx, time);
00729
00731
00735     mtk::Real yy = grid.south_bndy();
00736     (grid.discrete_field())[0] =
00737       ((grid.discrete_field())[0] + west_condition_(yy, time))/
      mtk::kTwo;
00738
00740     int west_offset{grid.num_cells_x() + 1 + 1};
00741     yy = yy + grid.delta_y()/mtk::kTwo;
00742     for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00743       #if MTK_VERBOSE_LEVEL > 2
00744       std::cout << "Adding on " << west_offset << "-th position." << std::endl;
00745       #endif
00746       (grid.discrete_field())[west_offset] =
00747         west_condition_(yy + ii*grid.delta_y(), time);
00748       west_offset += grid.num_cells_x() + 1 + 1;
00749     }
00750
00752     yy = grid.north_bndy();
00753     north_offset = (grid.num_cells_y() + 1)*(grid.num_cells_x() + 2);
00754     (grid.discrete_field())[north_offset] =
00755       ((grid.discrete_field())[north_offset] + west_condition_(yy, time))/
00756         mtk::kTwo;
00757
00759
00761     yy = grid.south_bndy();
00762     int east_offset{grid.num_cells_x() + 1};
00763     (grid.discrete_field())[east_offset] =
00764       ((grid.discrete_field())[east_offset] + east_condition_(yy, time))/
00765         mtk::kTwo;
00766
00768     yy = yy + grid.delta_y()/mtk::kTwo;
00769     for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00770       east_offset += grid.num_cells_x() + 1 + 1;
00771       #if MTK_VERBOSE_LEVEL > 2
00772       std::cout << "Adding on " << east_offset << "-th position." << std::endl;
00773       #endif
00774       (grid.discrete_field())[east_offset] =
00775         east_condition_(yy + ii*grid.delta_y(), time);
00776     }
00777
00779     yy = grid.north_bndy();
00780     (grid.discrete_field())[north_offset + grid.num_cells_x() + 1] =
00781       ((grid.discrete_field())[north_offset + grid.num_cells_x() + 1] +
00782       east_condition_(yy, time))/mtk::kTwo;
00783
00784   } else {
```

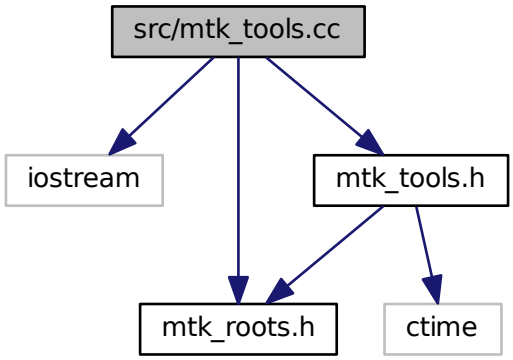
```
00785
00787
00789   }
00790 }
```

## 17.99 src/mtk_tools.cc File Reference

Implements a execution tool manager class.

```
#include <iostream>
#include "mtk_roots.h"
#include "mtk_tools.h"
```

Include dependency graph for mtk_tools.cc:




### 17.99.1 Detailed Description

Basic tools to ensure execution correctness.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_tools.cc.

## 17.100 mtk_tools.cc

```
00001
00010 /*
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00016
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```

```
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00054 */
00055
00056 #include <iostream>
00057
00058 #include "mtk_roots.h"
00059 #include "mtk_tools.h"
00060
00061 void mtk::Tools::Prevent(const bool condition,
00062                          const char *const fname,
00063                          int lineno,
00064                          const char *const fxname) noexcept {
00065
00067   if (lineno < 1) {
00068     std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00069     __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00070     exit(EXIT_FAILURE);
00071   }
00072
00073   if (condition) {
00074     std::cerr << fname << ": " << "Incorrect parameter at line " <<
00075     lineno << " (" << fxname << ")" << std::endl;
00076     exit(EXIT_FAILURE);
00077   }
00078 }
00079
00081
00082 int mtk::Tools::test_number_;  // Used to control the correctness of the test.
00083
00084 mtk::Real mtk::Tools::duration_;  // Duration of the current test.
00085
00086 clock_t mtk::Tools::begin_time_;  // Used to time tests.
00087
00088 void mtk::Tools::BeginUnitTestNo(const int &nn) noexcept {
00089
00090   #if MTK_PERFORM_PREVENTIONS
00091   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00092   #endif
00093
00094   test_number_ = nn;
00095
00096   std::cout << "Beginning test " << nn << "." << std::endl;
00097   begin_time_ = clock();
00098 }
00099
00100 void mtk::Tools::EndUnitTestNo(const int &nn) noexcept {
```

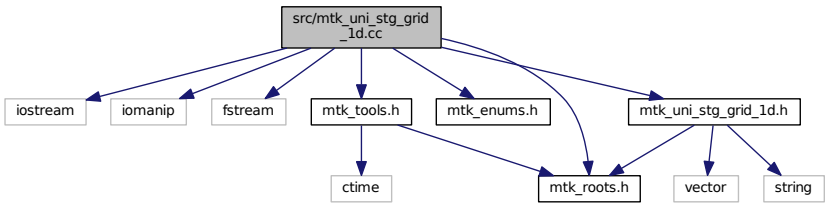
```
00101
00102   #if MTK_PERFORM_PREVENTIONS
00103   mtk::Tools::Prevent(test_number_ != nn, __FILE__, __LINE__, __func__);
00104   #endif
00105
00106   duration_ = mtk::Real(clock() - begin_time_)/CLOCKS_PER_SEC;
00107 }
00108
00109 void mtk::Tools::Assert(const bool &condition) noexcept {
00110
00111   if (condition) {
00112     std::cout << "Test " << test_number_ << ": PASSED in " << duration_ <<
00113       " s." << std::endl;
00114   } else {
00115     std::cout << "Test " << test_number_ << ": FAILED in " << duration_ <<
00116       " s." << std::endl;
00117   }
00118 }
```

## 17.101 src/mtk_uni_stg_grid_1d.cc File Reference

Implementation of an 1D uniform staggered grid.

```
#include <iostream>
#include <iomanip>
#include <fstream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk_uni_stg_grid_1d.cc:




### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid1D &in)

### 17.101.1 Detailed Description

Implementation of an 1D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_uni_stg_grid_1d.cc.

## 17.102 mtk_uni_stg_grid_1d.cc

```
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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00023 2. Redistributions of source code must be done through direct
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_enums.h"
00062 #include "mtk_tools.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00068 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid1D &in) {
00069
00070   stream << '[' << in.west_bndy_x_ << ':' << in.num_cells_x_ << ':' <<
00071   in.east_bndy_x_ << "] = " << std::endl << std::endl;
00072
00074
00075   stream << "x:";
00076   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00077     stream << std::setw(10) << in.discrete_domain_x_[ii];
```

```
00078   }
00079   stream << std::endl;
00080
00082
00083   if (in.nature_ == mtk::SCALAR) {
00084     stream << "u:";
00085   }
00086   else {
00087     stream << "v:";
00088   }
00089   for (unsigned int ii = 0; ii < in.discrete_field_.size(); ++ii) {
00090     stream << std::setw(10) << in.discrete_field_[ii];
00091   }
00092
00093   stream << std::endl;
00094
00095   return stream;
00096 }
00097 }
00098
00099 mtk::UniStgGrid1D::UniStgGrid1D():
00100     nature_(),
00101     discrete_domain_x_(),
00102     discrete_field_(),
00103     west_bndy_x_(),
00104     east_bndy_x_(),
00105     num_cells_x_(),
00106     delta_x_() {}
00107
00108 mtk::UniStgGrid1D::UniStgGrid1D(const
      UniStgGrid1D &grid):
00109     nature_(grid.nature_),
00110     west_bndy_x_(grid.west_bndy_x_),
00111     east_bndy_x_(grid.east_bndy_x_),
00112     num_cells_x_(grid.num_cells_x_),
00113     delta_x_(grid.delta_x_) {
00114
00115     std::copy(grid.discrete_domain_x_.begin(),
00116               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00117               discrete_domain_x_.begin());
00118
00119     std::copy(grid.discrete_field_.begin(),
00120               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00121               discrete_field_.begin());
00122 }
00123
00124 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00125                                 const Real &east_bndy_x,
00126                                 const int &num_cells_x,
00127                                 const mtk::FieldNature &nature) {
00128
00129   #ifdef MTK_PERFORM_PREVENTIONS
00130   mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00131   mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00132   mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00133   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00134   #endif
00135
00136   nature_ = nature;
00137   west_bndy_x_ = west_bndy_x;
00138   east_bndy_x_ = east_bndy_x;
00139   num_cells_x_ = num_cells_x;
00140
00141   delta_x_ = (east_bndy_x - west_bndy_x)/((mtk::Real) num_cells_x);
00142 }
00143
00144 mtk::UniStgGrid1D::~UniStgGrid1D() {}
00145
00146 mtk::Real mtk::UniStgGrid1D::west_bndy_x() const {
00147
00148   return west_bndy_x_;
00149 }
00150
00151 mtk::Real mtk::UniStgGrid1D::east_bndy_x() const {
00152
00153   return east_bndy_x_;
00154 }
00155
00156 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00157
```

```
00158   return delta_x_;
00159 }
00160
00161 const mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() const
    {
00162
00163   return discrete_domain_x_.data();
00164 }
00165
00166 mtk::Real *mtk::UniStgGrid1D::discrete_field() {
00167
00168   return discrete_field_.data();
00169 }
00170
00171 int mtk::UniStgGrid1D::num_cells_x() const {
00172
00173   return num_cells_x_;
00174 }
00175
00176 void mtk::UniStgGrid1D::BindScalarField(
00177     mtk::Real (*ScalarField)(const mtk::Real &xx)) {
00178
00179   #ifdef MTK_PERFORM_PREVENTIONS
00180   mtk::Tools::Prevent(nature_ == mtk::VECTOR, __FILE__, __LINE__, __func__);
00181   #endif
00182
00184
00185   discrete_domain_x_.reserve(num_cells_x_ + 2);
00186
00187   discrete_domain_x_.push_back(west_bndy_x_);
00188   #ifdef MTK_PRECISION_DOUBLE
00189   auto first_center = west_bndy_x_ + delta_x_/2.0;
00190   #else
00191   auto first_center = west_bndy_x_ + delta_x_/2.0f;
00192   #endif
00193   discrete_domain_x_.push_back(first_center);
00194   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00195     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00196   }
00197   discrete_domain_x_.push_back(east_bndy_x_);
00198
00200
00201   discrete_field_.reserve(num_cells_x_ + 2);
00202
00203   discrete_field_.push_back(ScalarField(west_bndy_x_));
00204
00205   discrete_field_.push_back(ScalarField(first_center));
00206   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00207     discrete_field_.push_back(ScalarField(first_center + ii*delta_x_));
00208   }
00209   discrete_field_.push_back(ScalarField(east_bndy_x_));
00210 }
00211
00212 void mtk::UniStgGrid1D::BindVectorField(
00213     mtk::Real (*VectorField)(mtk::Real xx)) {
00214
00215   #ifdef MTK_PERFORM_PREVENTIONS
00216   mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00217   #endif
00218
00220
00221   discrete_domain_x_.reserve(num_cells_x_ + 1);
00222
00223   discrete_domain_x_.push_back(west_bndy_x_);
00224   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00225     discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00226   }
00227   discrete_domain_x_.push_back(east_bndy_x_);
00228
00230
00231   discrete_field_.reserve(num_cells_x_ + 1);
00232
00233   discrete_field_.push_back(VectorField(west_bndy_x_));
00234   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00235     discrete_field_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00236   }
00237   discrete_field_.push_back(VectorField(east_bndy_x_));
00238 }
00239
00240 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00241                                     std::string space_name,
```

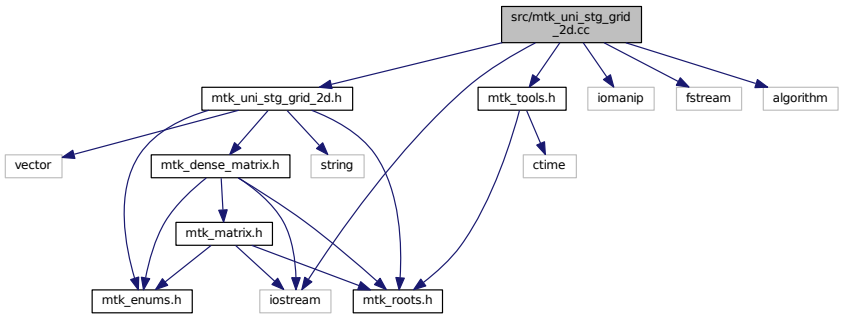
```
00242                                     std::string field_name) const {
00243
00244   std::ofstream output_dat_file;  // Output file.
00245
00246   output_dat_file.open(filename);
00247
00248   if (!output_dat_file.is_open()) {
00249     return false;
00250   }
00251
00252   output_dat_file << "# " << space_name <<  ' ' << field_name << std::endl;
00253   for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00254     output_dat_file << discrete_domain_x_[ii] << ' ' << discrete_field_[ii] <<
00255       std::endl;
00256   }
00257
00258   output_dat_file.close();
00259
00260   return true;
00261 }
```

## 17.103 src/mtk_uni_stg_grid_2d.cc File Reference

Implementation of a 2D uniform staggered grid.

```
#include <iostream>
#include <iomanip>
#include <fstream>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_uni_stg_grid_2d.cc:




### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid2D &in)

### 17.103.1 Detailed Description

Implementation of a 2D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_uni_stg_grid_2d.cc.

## 17.104 mtk_uni_stg_grid_2d.cc

```
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00010 /*
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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include <algorithm>
00061
00062 #include "mtk_tools.h"
00063 #include "mtk_uni_stg_grid_2d.h"
00064
00065 namespace mtk {
00066
00067 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid2D &in) {
00068
00069   stream << '[' << in.west_bndy_ << ':' << in.num_cells_x_ << ':' <<
```

```
00070   in.east_bndy_ << "] x ";
00071
00072   stream << '[' << in.south_bndy_ << ':' << in.num_cells_y_ << ':' <<
00073   in.north_bndy_ << "] = " << std::endl << std::endl;
00074
00076
00077   stream << "x:";
00078   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00079     stream << std::setw(10) << in.discrete_domain_x_[ii];
00080   }
00081   stream << std::endl;
00082
00083   stream << "y:";
00084   for (unsigned int ii = 0; ii < in.discrete_domain_y_.size(); ++ii) {
00085     stream << std::setw(10) << in.discrete_domain_y_[ii];
00086   }
00087   stream << std::endl;
00088
00090
00091   if (in.nature_ == mtk::SCALAR) {
00092     stream << "u:" << std::endl;
00093     if (in.discrete_field_.size() > 0) {
00094       for (int ii = 0; ii < in.num_cells_x_ + 2; ++ii) {
00095         for (int jj = 0; jj < in.num_cells_y_ + 2; ++jj) {
00096           stream << std::setw(10) << in.discrete_field_[ii*in.
      num_cells_y_ + jj];
00097         }
00098         stream << std::endl;
00099       }
00100     }
00101   } else {
00102
00103     int mm{in.num_cells_x_};
00104     int nn{in.num_cells_y_};
00105     int p_offset{nn*(mm + 1) - 1};
00106
00107     stream << "p(x,y):" << std::endl;
00108     for (int ii = 0; ii < nn; ++ii) {
00109       for (int jj = 0; jj < mm + 1; ++jj) {
00110         stream << std::setw(10) << in.discrete_field_[ii*(mm + 1) + jj];
00111       }
00112       stream << std::endl;
00113     }
00114     stream << std::endl;
00115
00116     stream << "q(x,y):" << std::endl;
00117     for (int ii = 0; ii < nn + 1; ++ii) {
00118       for (int jj = 0; jj < mm; ++jj) {
00119         stream << std::setw(10) <<
00120           in.discrete_field_[p_offset + ii*mm + jj];
00121       }
00122       stream << std::endl;
00123     }
00124     stream << std::endl;
00125   }
00126
00127   return stream;
00128 }
00129 }
00130
00131 mtk::UniStgGrid2D::UniStgGrid2D():
00132     discrete_domain_x_(),
00133     discrete_domain_y_(),
00134     discrete_field_(),
00135     nature_(),
00136     west_bndy_(),
00137     east_bndy_(),
00138     num_cells_x_(),
00139     delta_x_(),
00140     south_bndy_(),
00141     north_bndy_(),
00142     num_cells_y_(),
00143     delta_y_() {}
00144
00145 mtk::UniStgGrid2D::UniStgGrid2D(const
      UniStgGrid2D &grid):
00146     nature_(grid.nature_),
00147     west_bndy_(grid.west_bndy_),
00148     east_bndy_(grid.east_bndy_),
00149     num_cells_x_(grid.num_cells_x_),
00150     delta_x_(grid.delta_x_),
```

```
00151     south_bndy_(grid.south_bndy_),
00152     north_bndy_(grid.north_bndy_),
00153     num_cells_y_(grid.num_cells_y_),
00154     delta_y_(grid.delta_y_) {
00155
00156     std::copy(grid.discrete_domain_x_.begin(),
00157               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00158               discrete_domain_x_.begin());
00159
00160     std::copy(grid.discrete_domain_y_.begin(),
00161               grid.discrete_domain_y_.begin() + grid.
      discrete_domain_y_.size(),
00162               discrete_domain_y_.begin());
00163
00164     std::copy(grid.discrete_field_.begin(),
00165               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00166               discrete_field_.begin());
00167 }
00168
00169 mtk::UniStgGrid2D::UniStgGrid2D(const Real &west_bndy,
00170                                 const Real &east_bndy,
00171                                 const int &num_cells_x,
00172                                 const Real &south_bndy,
00173                                 const Real &north_bndy,
00174                                 const int &num_cells_y,
00175                                 const mtk::FieldNature &nature) {
00176
00177   #ifdef MTK_PERFORM_PREVENTIONS
00178   mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00179   mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00180   mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00182   mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00183   mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00184   mtk::Tools::Prevent(north_bndy <= south_bndy,
00185                       __FILE__, __LINE__, __func__);
00186   mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00187   #endif
00188
00189   nature_ = nature;
00190
00191   west_bndy_ = west_bndy;
00192   east_bndy_ = east_bndy;
00193   num_cells_x_ = num_cells_x;
00194
00195   south_bndy_ = south_bndy;
00196   north_bndy_ = north_bndy;
00197   num_cells_y_ = num_cells_y;
00198
00199   delta_x_ = (east_bndy_ - west_bndy_)/((mtk::Real) num_cells_x);
00200   delta_y_ = (north_bndy_ - south_bndy_)/((mtk::Real) num_cells_y);
00201 }
00202
00203 mtk::UniStgGrid2D::~UniStgGrid2D() {}
00204
00205 mtk::FieldNature mtk::UniStgGrid2D::nature() const {
00206
00207   return nature_;
00208 }
00209
00210 mtk::Real mtk::UniStgGrid2D::west_bndy() const {
00211
00212   return west_bndy_;
00213 }
00214
00215 mtk::Real mtk::UniStgGrid2D::east_bndy() const {
00216
00217   return east_bndy_;
00218 }
00219
00220 int mtk::UniStgGrid2D::num_cells_x() const {
00221
00222   return num_cells_x_;
00223 }
00224
00225 mtk::Real mtk::UniStgGrid2D::delta_x() const {
00226
00227   return delta_x_;
00228 }
00229
```

```
00230 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_x() const
      {
00231
00232   return discrete_domain_x_.data();
00233 }
00234
00235 mtk::Real mtk::UniStgGrid2D::south_bndy() const {
00236
00237   return south_bndy_;
00238 }
00239
00240 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00241
00242   return north_bndy_;
00243 }
00244
00245 int mtk::UniStgGrid2D::num_cells_y() const {
00246
00247   return num_cells_y_;
00248 }
00249
00250 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00251
00252   return delta_y_;
00253 }
00254
00255 bool mtk::UniStgGrid2D::Bound() const {
00256
00257   return discrete_field_.size() != 0;
00258 }
00259
00260 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_y() const
      {
00261
00262   return discrete_domain_y_.data();
00263 }
00264
00265 mtk::Real* mtk::UniStgGrid2D::discrete_field() {
00266
00267   return discrete_field_.data();
00268 }
00269
00270 int mtk::UniStgGrid2D::Size() const {
00271
00272   return discrete_field_.size();
00273 }
00274
00275 void mtk::UniStgGrid2D::BindScalarField(
00276     Real (*ScalarField)(const Real &xx, const Real &yy)) {
00277
00278   #ifdef MTK_PERFORM_PREVENTIONS
00279   mtk::Tools::Prevent(nature_ != mtk::SCALAR, __FILE__, __LINE__, __func__);
00280   #endif
00281
00283
00284   discrete_domain_x_.reserve(num_cells_x_ + 2);
00285
00286   discrete_domain_x_.push_back(west_bndy_);
00287   #ifdef MTK_PRECISION_DOUBLE
00288   auto first_center = west_bndy_ + delta_x_/2.0;
00289   #else
00290   auto first_center = west_bndy_ + delta_x_/2.0f;
00291   #endif
00292   discrete_domain_x_.push_back(first_center);
00293   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00294     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00295   }
00296   discrete_domain_x_.push_back(east_bndy_);
00297
00299
00300   discrete_domain_y_.reserve(num_cells_y_ + 2);
00301
00302   discrete_domain_y_.push_back(south_bndy_);
00303   #ifdef MTK_PRECISION_DOUBLE
00304   first_center = south_bndy_ + delta_x_/2.0;
00305   #else
00306   first_center = south_bndy_ + delta_x_/2.0f;
00307   #endif
00308   discrete_domain_y_.push_back(first_center);
00309   for (auto ii = 1; ii < num_cells_y_; ++ii) {
00310     discrete_domain_y_.push_back(first_center + ii*delta_y_);
```

```
00311   }
00312   discrete_domain_y_.push_back(north_bndy_);
00313
00315
00316   discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));
00317
00318   for (int ii = 0; ii < num_cells_y_ + 2; ++ii) {
00319     for (int jj = 0; jj < num_cells_x_ + 2; ++jj) {
00320       #if MTK_VERBOSE_LEVEL > 6
00321       std::cout << "Pushing value for x = " << discrete_domain_x_[jj] <<
00322         " y = " << discrete_domain_y_[ii] << std::endl;
00323       #endif
00324       discrete_field_.push_back(ScalarField(discrete_domain_x_[jj],
00325                                             discrete_domain_y_[ii]));
00326     }
00327   }
00328 }
00329
00330 void mtk::UniStgGrid2D::BindVectorFieldPComponent(
00331   mtk::Real (*VectorField)(const mtk::Real &xx, const
      mtk::Real &yy)) {
00332
00333   int mm{num_cells_x_};
00334   int nn{num_cells_y_};
00335
00336   int total{nn*(mm + 1) + mm*(nn + 1)};
00337
00338   #ifdef MTK_PRECISION_DOUBLE
00339   double half_delta_x{delta_x_/2.0};
00340   double half_delta_y{delta_y_/2.0};
00341   #else
00342   float half_delta_x{delta_x_/2.0f};
00343   float half_delta_y{delta_y_/2.0f};
00344   #endif
00345
00347
00348   // We need every data point of the discrete domain; i.e. we need all the
00349   // nodes and all the centers. There are mm centers for the x direction, and
00350   // nn centers for the y direction. Since there is one node per center, that
00351   // amounts to 2*mm. If we finally consider the final boundary node, it
00352   // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00353   // y direction, this amounts to 2*nn + 1.
00354
00355   discrete_domain_x_.reserve(2*mm + 1);
00356
00357   discrete_domain_x_.push_back(west_bndy_);
00358   for (int ii = 1; ii < (2*mm + 1); ++ii) {
00359     discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00360   }
00361
00363
00364   discrete_domain_y_.reserve(2*nn + 1);
00365
00366   discrete_domain_y_.push_back(south_bndy_);
00367   for (int ii = 1; ii < (2*nn + 1); ++ii) {
00368     discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00369   }
00370
00372
00373   discrete_field_.reserve(total);
00374
00375   // For each y-center.
00376   for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00377
00378     // Bind all of the x-nodes for this y-center.
00379     for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00380       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00381                                             discrete_domain_y_[ii]));
00382
00383       #if MTK_VERBOSE_LEVEL > 6
00384       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00385         discrete_domain_y_[ii] << " = " <<
00386         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00387       #endif
00388     }
00389   }
00390   #if MTK_VERBOSE_LEVEL > 6
00391   std::cout << std::endl;
00392   #endif
00393 }
00394
```

```
00395 void mtk::UniStgGrid2D::BindVectorFieldQComponent(
00396   mtk::Real (*VectorField)(const mtk::Real &xx, const
      mtk::Real &yy)) {
00397
00398   int mm{num_cells_x_};
00399   int nn{num_cells_y_};
00400
00402
00403   // For each y-node.
00404   for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00405
00406     // Bind all of the x-center for this y-node.
00407     for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00408       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00409                                             discrete_domain_y_[ii]));
00410
00411       #if MTK_VERBOSE_LEVEL > 6
00412       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00413         discrete_domain_y_[ii] << " = " <<
00414         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00415       #endif
00416     }
00417   }
00418   #if MTK_VERBOSE_LEVEL > 6
00419   std::cout << std::endl;
00420   #endif
00421 }
00422
00423 void mtk::UniStgGrid2D::BindVectorField(
00424   Real (*VectorFieldPComponent)(const Real &xx, const Real &yy),
00425   Real (*VectorFieldQComponent)(const Real &xx, const Real &yy)) {
00426
00427   #ifdef MTK_PERFORM_PREVENTIONS
00428   mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00429   #endif
00430
00431   BindVectorFieldPComponent(VectorFieldPComponent);
00432   BindVectorFieldQComponent(VectorFieldQComponent);
00433 }
00434
00435 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00436                                     std::string space_name_x,
00437                                     std::string space_name_y,
00438                                     std::string field_name) const {
00439
00440   std::ofstream output_dat_file;  // Output file.
00441
00442   output_dat_file.open(filename);
00443
00444   if (!output_dat_file.is_open()) {
00445     return false;
00446   }
00447
00448   if (nature_ == mtk::SCALAR) {
00449     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00450       field_name << std::endl;
00451
00452     int idx{};
00453     for (unsigned int ii = 0; ii < discrete_domain_y_.size(); ++ii) {
00454       for (unsigned int jj = 0; jj < discrete_domain_x_.size(); ++jj) {
00455         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00456                            discrete_domain_y_[ii] << ' ' <<
00457                            discrete_field_[idx] <<
00458                           std::endl;
00459         idx++;
00460       }
00461       output_dat_file << std::endl;
00462     }
00463   } else {
00464     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00465       field_name << std::endl;
00466
00467     output_dat_file << "# Horizontal component:" << std::endl;
00468
00469     int mm{num_cells_x_};
00470     int nn{num_cells_y_};
00471
00473
00474     // For each y-center.
00475     int idx{};
00476     for (int ii = 1; ii < 2*nn + 1; ii += 2) {
```

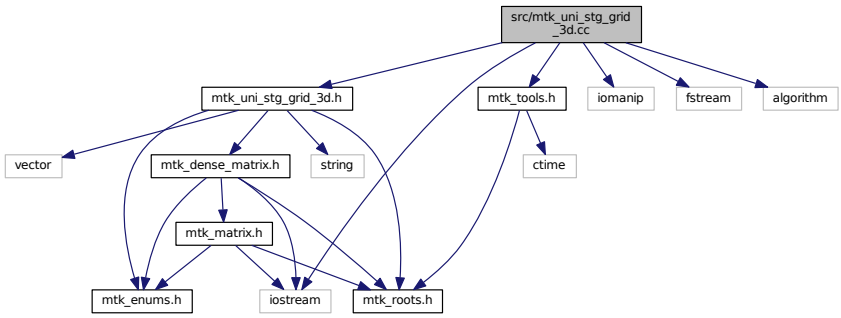
```
00477       // Bind all of the x-nodes for this y-center.
00478       for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00479
00480         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00481           discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<
00482           mtk::kZero << std::endl;
00483
00484         ++idx;
00485       }
00486     }
00487
00489     int p_offset{nn*(mm + 1) - 1};
00490     idx = 0;
00491     output_dat_file << "# Vertical component:" << std::endl;
00492     // For each y-node.
00493     for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00494       // Bind all of the x-center for this y-node.
00495       for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00496
00497         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00498           discrete_domain_y_[ii] << ' ' << mtk::kZero << ' ' <<
00499           discrete_field_[p_offset + idx] << std::endl;
00500
00501         ++idx;
00502       }
00503     }
00504   }
00505
00506   output_dat_file.close();
00507
00508   return true;
00509 }
```

## 17.105 src/mtk_uni_stg_grid_3d.cc File Reference

Implementation of a 2D uniform staggered grid.

```
#include <iostream>
#include <iomanip>
#include <fstream>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_uni_stg_grid_3d.cc:




### Namespaces

- mtk

*Mimetic Methods Toolkit namespace.*

### Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid3D &in)

### 17.105.1 Detailed Description

Implementation of a 2D uniform staggered grid.

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_uni_stg_grid_3d.cc.

## 17.106 mtk_uni_stg_grid_3d.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
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00037
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00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
```

```
00059
00060 #include <algorithm>
00061
00062 #include "mtk_tools.h"
00063 #include "mtk_uni_stg_grid_3d.h"
00064
00065 namespace mtk {
00066
00067 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid3D &in) {
00068
00069   stream << '[' << in.west_bndy_ << ':' << in.num_cells_x_ << ':' <<
00070   in.east_bndy_ << "] x ";
00071
00072   stream << '[' << in.south_bndy_ << ':' << in.num_cells_y_ << ':' <<
00073   in.north_bndy_ << "] x ";
00074
00075   stream << '[' << in.bottom_bndy_ << ':' << in.num_cells_z_ << ':' <<
00076   in.top_bndy_ << "] = " << std::endl << std::endl;
00077
00079
00080   stream << "x:";
00081   for (auto const &cc: in.discrete_domain_x_) {
00082     stream << std::setw(10) << cc;
00083   }
00084   stream << std::endl;
00085
00086   stream << "y:";
00087   for (auto const &cc: in.discrete_domain_y_) {
00088     stream << std::setw(10) << cc;
00089   }
00090   stream << std::endl;
00091
00092   stream << "z:";
00093   for (auto const &cc: in.discrete_domain_z_) {
00094     stream << std::setw(10) << cc;
00095   }
00096   stream << std::endl;
00097
00099
00100   if (in.nature_ == mtk::SCALAR) {
00101     stream << "u(x,y,z):" << std::endl;
00102     if (in.discrete_field_.size() > 0) {
00103
00104     }
00105   } else {
00106     stream << "p(x,y,z):" << std::endl;
00107     stream << "q(x,y.z):" << std::endl;
00108     if (in.discrete_field_.size() > 0) {
00109
00110     }
00111   }
00112   return stream;
00113 }
00114 }
00115
00116 mtk::UniStgGrid3D::UniStgGrid3D():
00117     discrete_domain_x_(),
00118     discrete_domain_y_(),
00119     discrete_domain_z_(),
00120     discrete_field_(),
00121     nature_(),
00122     west_bndy_(),
00123     east_bndy_(),
00124     num_cells_x_(),
00125     delta_x_(),
00126     south_bndy_(),
00127     north_bndy_(),
00128     num_cells_y_(),
00129     delta_y_(),
00130     bottom_bndy_(),
00131     top_bndy_(),
00132     num_cells_z_(),
00133     delta_z_() {}
00134
00135 mtk::UniStgGrid3D::UniStgGrid3D(const
      UniStgGrid3D &grid):
00136     nature_(grid.nature_),
00137     west_bndy_(grid.west_bndy_),
00138     east_bndy_(grid.east_bndy_),
00139     num_cells_x_(grid.num_cells_x_),
00140     delta_x_(grid.delta_x_),
```

```
00141     south_bndy_(grid.south_bndy_),
00142     north_bndy_(grid.north_bndy_),
00143     num_cells_y_(grid.num_cells_y_),
00144     delta_y_(grid.delta_y_),
00145     bottom_bndy_(grid.bottom_bndy_),
00146     top_bndy_(grid.top_bndy_),
00147     num_cells_z_(grid.num_cells_z_),
00148     delta_z_(grid.delta_z_) {
00149
00150     std::copy(grid.discrete_domain_x_.begin(),
00151               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00152               discrete_domain_x_.begin());
00153
00154     std::copy(grid.discrete_domain_y_.begin(),
00155               grid.discrete_domain_y_.begin() + grid.
      discrete_domain_y_.size(),
00156               discrete_domain_y_.begin());
00157
00158     std::copy(grid.discrete_domain_z_.begin(),
00159               grid.discrete_domain_z_.begin() + grid.
      discrete_domain_z_.size(),
00160               discrete_domain_z_.begin());
00161
00162     std::copy(grid.discrete_field_.begin(),
00163               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00164               discrete_field_.begin());
00165 }
00166
00167 mtk::UniStgGrid3D::UniStgGrid3D(const Real &west_bndy,
00168                                 const Real &east_bndy,
00169                                 const int &num_cells_x,
00170                                 const Real &south_bndy,
00171                                 const Real &north_bndy,
00172                                 const int &num_cells_y,
00173                                 const Real &bottom_bndy,
00174                                 const Real &top_bndy,
00175                                 const int &num_cells_z,
00176                                 const mtk::FieldNature &nature) {
00177
00178   #ifdef MTK_PERFORM_PREVENTIONS
00179   mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00180   mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00182   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00183   mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00184   mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00185   mtk::Tools::Prevent(north_bndy <= south_bndy,
00186                       __FILE__, __LINE__, __func__);
00187   mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00188   mtk::Tools::Prevent(bottom_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00189   mtk::Tools::Prevent(top_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00190   mtk::Tools::Prevent(top_bndy <= bottom_bndy,
00191                       __FILE__, __LINE__, __func__);
00192   mtk::Tools::Prevent(num_cells_z < 0, __FILE__, __LINE__, __func__);
00193   #endif
00194
00195   nature_ = nature;
00196
00197   west_bndy_ = west_bndy;
00198   east_bndy_ = east_bndy;
00199   num_cells_x_ = num_cells_x;
00200
00201   south_bndy_ = south_bndy;
00202   north_bndy_ = north_bndy;
00203   num_cells_y_ = num_cells_y;
00204
00205   bottom_bndy_ = bottom_bndy;
00206   top_bndy_ = top_bndy;
00207   num_cells_z_ = num_cells_z;
00208
00209   delta_x_ = (east_bndy_ - west_bndy_)/((mtk::Real) num_cells_x);
00210   delta_y_ = (north_bndy_ - south_bndy_)/((mtk::Real) num_cells_y);
00211   delta_z_ = (top_bndy_ - bottom_bndy_)/((mtk::Real) num_cells_z);
00212 }
00213
00214 mtk::UniStgGrid3D::~UniStgGrid3D() {}
00215
00216 mtk::FieldNature mtk::UniStgGrid3D::nature() const {
00217
00218   return nature_;
```

```
00219 }
00220
00221 mtk::Real mtk::UniStgGrid3D::west_bndy() const {
00222
00223   return west_bndy_;
00224 }
00225
00226 mtk::Real mtk::UniStgGrid3D::east_bndy() const {
00227
00228   return east_bndy_;
00229 }
00230
00231 int mtk::UniStgGrid3D::num_cells_x() const {
00232
00233   return num_cells_x_;
00234 }
00235
00236 mtk::Real mtk::UniStgGrid3D::delta_x() const {
00237
00238   return delta_x_;
00239 }
00240
00241 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_x() const
     {
00242
00243   return discrete_domain_x_.data();
00244 }
00245
00246 mtk::Real mtk::UniStgGrid3D::south_bndy() const {
00247
00248   return south_bndy_;
00249 }
00250
00251 mtk::Real mtk::UniStgGrid3D::north_bndy() const {
00252
00253   return north_bndy_;
00254 }
00255
00256 int mtk::UniStgGrid3D::num_cells_y() const {
00257
00258   return num_cells_y_;
00259 }
00260
00261 mtk::Real mtk::UniStgGrid3D::delta_y() const {
00262
00263   return delta_y_;
00264 }
00265
00266 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_y() const
     {
00267
00268   return discrete_domain_y_.data();
00269 }
00270
00271 mtk::Real mtk::UniStgGrid3D::bottom_bndy() const {
00272
00273   return bottom_bndy_;
00274 }
00275
00276 mtk::Real mtk::UniStgGrid3D::top_bndy() const {
00277
00278   return top_bndy_;
00279 }
00280
00281 int mtk::UniStgGrid3D::num_cells_z() const {
00282
00283   return num_cells_z_;
00284 }
00285
00286 mtk::Real mtk::UniStgGrid3D::delta_z() const {
00287
00288   return delta_z_;
00289 }
00290
00291 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_z() const
     {
00292
00293   return discrete_domain_z_.data();
00294 }
00295
00296 mtk::Real* mtk::UniStgGrid3D::discrete_field() {
```

```
00297
00298   return discrete_field_.data();
00299 }
00300
00301 bool mtk::UniStgGrid3D::Bound() const {
00302
00303   return discrete_field_.size() != 0;
00304 }
00305
00306 int mtk::UniStgGrid3D::Size() const {
00307
00308   return discrete_field_.size();
00309 }
00310
00311 void mtk::UniStgGrid3D::BindScalarField(
00312     mtk::Real (*ScalarField)(const mtk::Real &xx,
00313                              const mtk::Real &yy,
00314                              const mtk::Real &zz)) {
00315
00316   #ifdef MTK_PERFORM_PREVENTIONS
00317   mtk::Tools::Prevent(nature_ != mtk::SCALAR, __FILE__, __LINE__, __func__);
00318   #endif
00319
00321
00322   discrete_domain_x_.reserve(num_cells_x_ + 2);
00323
00324   discrete_domain_x_.push_back(west_bndy_);
00325   #ifdef MTK_PRECISION_DOUBLE
00326   auto first_center = west_bndy_ + delta_x_/2.0;
00327   #else
00328   auto first_center = west_bndy_ + delta_x_/2.0f;
00329   #endif
00330   discrete_domain_x_.push_back(first_center);
00331   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00332     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00333   }
00334   discrete_domain_x_.push_back(east_bndy_);
00335
00337
00338   discrete_domain_y_.reserve(num_cells_y_ + 2);
00339
00340   discrete_domain_y_.push_back(south_bndy_);
00341   #ifdef MTK_PRECISION_DOUBLE
00342   first_center = south_bndy_ + delta_x_/2.0;
00343   #else
00344   first_center = south_bndy_ + delta_x_/2.0f;
00345   #endif
00346   discrete_domain_y_.push_back(first_center);
00347   for (auto ii = 1; ii < num_cells_y_; ++ii) {
00348     discrete_domain_y_.push_back(first_center + ii*delta_y_);
00349   }
00350   discrete_domain_y_.push_back(north_bndy_);
00351
00353
00354   discrete_domain_z_.reserve(num_cells_z_ + 2);
00355
00356   discrete_domain_z_.push_back(bottom_bndy_);
00357   first_center = bottom_bndy_ + delta_z_/mtk::kTwo;
00358   discrete_domain_z_.push_back(first_center);
00359   for (auto ii = 1; ii < num_cells_z_; ++ii) {
00360     discrete_domain_z_.push_back(first_center + ii*delta_z_);
00361   }
00362   discrete_domain_z_.push_back(top_bndy_);
00363
00365
00366   int aux{(num_cells_x_ + 2)*(num_cells_y_ + 2)*(num_cells_z_ + 2)};
00367
00368   discrete_field_.reserve(aux);
00369
00370   // ...
00371 }
00372
00373 void mtk::UniStgGrid3D::BindVectorFieldPComponent(
00374   mtk::Real (*VectorField)(const mtk::Real &xx,
00375                            const mtk::Real &yy,
00376                            const mtk::Real &zz)) {
00377
00378 }
00379
00380 void mtk::UniStgGrid3D::BindVectorFieldQComponent(
00381   mtk::Real (*VectorField)(const mtk::Real &xx,
```

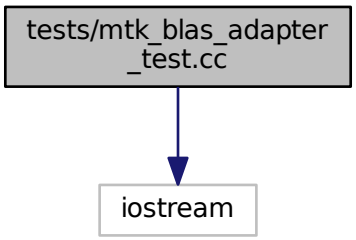
```
00382                            const mtk::Real &yy,
00383                            const mtk::Real &zz)) {
00384
00385 }
00386
00387 void mtk::UniStgGrid3D::BindVectorFieldRComponent(
00388   mtk::Real (*VectorField)(const mtk::Real &xx,
00389                            const mtk::Real &yy,
00390                            const mtk::Real &zz)) {
00391
00392 }
00393
00394 void mtk::UniStgGrid3D::BindVectorField(
00395   mtk::Real (*VectorFieldPComponent)(const mtk::Real &xx,
00396                                      const mtk::Real &yy,
00397                                      const mtk::Real &zz),
00398   mtk::Real (*VectorFieldQComponent)(const mtk::Real &xx,
00399                                      const mtk::Real &yy,
00400                                      const mtk::Real &zz),
00401   mtk::Real (*VectorFieldRComponent)(const mtk::Real &xx,
00402                                      const mtk::Real &yy,
00403                                      const mtk::Real &zz)) {
00404
00405   #ifdef MTK_PERFORM_PREVENTIONS
00406   mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00407   #endif
00408
00409   BindVectorFieldPComponent(VectorFieldPComponent);
00410   BindVectorFieldQComponent(VectorFieldQComponent);
00411 }
00412
00413 bool mtk::UniStgGrid3D::WriteToFile(std::string filename,
00414                                     std::string space_name_x,
00415                                     std::string space_name_y,
00416                                     std::string space_name_z,
00417                                     std::string field_name) const {
00418
00419   std::ofstream output_dat_file;  // Output file.
00420
00421   output_dat_file.open(filename);
00422
00423   if (!output_dat_file.is_open()) {
00424     return false;
00425   }
00426
00427   if (nature_ == mtk::SCALAR) {
00428     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00429       space_name_z << ' ' << field_name << std::endl;
00430
00431   } else {
00432     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00433       space_name_z << ' ' << field_name << std::endl;
00434
00435   }
00436
00437   output_dat_file.close();
00438
00439   return true;
00440 }
```

## 17.107 tests/mtk_blas_adapter_test.cc File Reference

Test file for the mtk::BLASAdapter class.

```
#include <iostream>
```

Include dependency graph for mtk_blas_adapter_test.cc:




## Functions

- int main ()

### 17.107.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_blas_adapter_test.cc.

### 17.107.2 Function Documentation

#### 17.107.2.1 int main ( )

Definition at line 109 of file mtk_blas_adapter_test.cc.

## 17.108 mtk_blas_adapter_test.cc

```
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00008 /*
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

```
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestRealDenseMM() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   int rr = 2;
00065   int cc = 3;
00066
00067   mtk::DenseMatrix aa(rr,cc);
00068
00069   aa.SetValue(0,0,1.0);
00070   aa.SetValue(0,1,2.0);
00071   aa.SetValue(0,2,3.0);
00072   aa.SetValue(1,0,4.0);
00073   aa.SetValue(1,1,5.0);
00074   aa.SetValue(1,2,6.0);
00075
00076   mtk::DenseMatrix bb(cc,rr);
00077
00078   bb.SetValue(0,0,7.0);
00079   bb.SetValue(0,1,8.0);
00080   bb.SetValue(1,0,9.0);
00081   bb.SetValue(1,1,10.0);
00082   bb.SetValue(2,0,11.0);
00083   bb.SetValue(2,1,12.0);
00084
00085   mtk::DenseMatrix pp = mtk::BLASAdapter::RealDenseMM(aa,bb);
00086
00087   mtk::DenseMatrix ff(rr,rr);
00088
00089   ff.SetValue(0,0,58.0);
00090   ff.SetValue(0,1,64.00);
00091   ff.SetValue(1,0,139.0);
00092   ff.SetValue(1,1,154.0);
00093
00094   mtk::Tools::EndUnitTestNo(1);
00095   mtk::Tools::Assert(pp == ff);
00096 }
00097
00098 int main () {
00099
00100   std::cout << "Testing mtk::BLASAdapter class." << std::endl;
00101
00102   TestRealDenseMM();
00103 }
00104
```
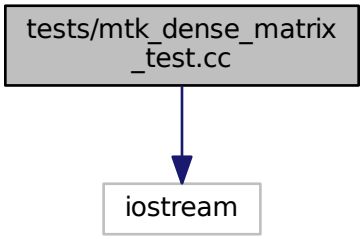

```
00105 #else
00106 #include <iostream>
00107 using std::cout;
00108 using std::endl;
00109 int main () {
00110   cout << "This code HAS to be compiled with support for C++11." << endl;
00111   cout << "Exiting..." << endl;
00112 }
00113 #endif
```

## 17.109 tests/mtk_dense_matrix_test.cc File Reference

Test file for the mtk::DenseMatrix class.

`#include <iostream>`
Include dependency graph for mtk_dense_matrix_test.cc:




### Functions

- int main ()

### 17.109.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_dense_matrix_test.cc.

### 17.109.2 Function Documentation

#### 17.109.2.1 int main ( )

Definition at line 330 of file mtk_dense_matrix_test.cc.

## 17.110 mtk_dense_matrix_test.cc

```
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00008 /*
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00012 Redistribution and use in source and binary forms, with or without modification,
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructor() {
00062
00063   mtk::Tools::BeginUnitTestNo(1);
00064
00065   mtk::DenseMatrix m1;
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068   mtk::Tools::Assert(m1.data() == nullptr);
00069 }
00070
00071 void TestConstructorWithNumRowsNumCols() {
00072
00073   mtk::Tools::BeginUnitTestNo(2);
00074
00075   int rr = 4;
00076   int cc = 7;
00077
00078   mtk::DenseMatrix m2(rr,cc);
00079
00080   mtk::Tools::EndUnitTestNo(2);
00081
00082   bool assertion =
00083     m2.data() != nullptr && m2.num_rows() == rr && m2.num_cols() == cc;
00084
```

```
00085   mtk::Tools::Assert(assertion);
00086 }
00087
00088 void TestConstructAsIdentity() {
00089
00090   mtk::Tools::BeginUnitTestNo(3);
00091
00092   int rank = 5;
00093   bool padded = true;
00094   bool transpose = false;
00095
00096   mtk::DenseMatrix m3(rank,padded,transpose);
00097
00098   mtk::DenseMatrix rr(rank + 2,rank);
00099
00100   for (int ii = 0; ii < rank; ++ii) {
00101     rr.SetValue(ii + 1, ii, mtk::kOne);
00102   }
00103
00104   mtk::Tools::EndUnitTestNo(3);
00105   mtk::Tools::Assert(m3 == rr);
00106 }
00107
00108   void TestConstructAsVandermonde() {
00109
00110   mtk::Tools::BeginUnitTestNo(4);
00111
00112   int rank = 5;
00113   bool padded = false;
00114   bool transpose = false;
00115
00116   mtk::DenseMatrix m4(rank,padded,transpose);
00117
00118   mtk::DenseMatrix rr(rank,rank);
00119
00120   for (int ii = 0; ii < rank; ++ii) {
00121     rr.SetValue(ii, ii, mtk::kOne);
00122   }
00123
00124   mtk::Tools::EndUnitTestNo(4);
00125   mtk::Tools::Assert(m4 == rr);
00126 }
00127
00128 void TestSetValueGetValue() {
00129
00130   mtk::Tools::BeginUnitTestNo(5);
00131
00132   int rr = 4;
00133   int cc = 7;
00134
00135   mtk::DenseMatrix m5(rr,cc);
00136
00137   for (auto ii = 0; ii < rr; ++ii) {
00138     for (auto jj = 0; jj < cc; ++jj) {
00139       m5.SetValue(ii,jj,(mtk::Real) ii + jj);
00140     }
00141   }
00142
00143   mtk::Real *vals = m5.data();
00144
00145   bool assertion{true};
00146
00147   for (auto ii = 0; ii < rr && assertion; ++ii) {
00148     for (auto jj = 0; jj < cc  && assertion; ++jj) {
00149       assertion = assertion && m5.GetValue(ii,jj) == vals[ii*cc + jj];
00150     }
00151   }
00152
00153   mtk::Tools::EndUnitTestNo(5);
00154   mtk::Tools::Assert(assertion);
00155 }
00156
00157 void TestConstructAsVandermondeTranspose() {
00158
00159   mtk::Tools::BeginUnitTestNo(6);
00160
00161   bool transpose = false;
00162   int generator_length = 3;
00163   int progression_length = 4;
00164
00165   mtk::Real generator[] = {-0.5, 0.5, 1.5};
```

```
00166
00167   mtk::DenseMatrix m6(generator,generator_length,progression_length,transpose);
00168
00169   transpose = true;
00170
00171   mtk::DenseMatrix m7(generator,generator_length,progression_length,transpose);
00172   mtk::DenseMatrix rr(progression_length, generator_length);
00173
00174   rr.SetValue(0, 0, 1.0);
00175   rr.SetValue(0, 1, 1.0);
00176   rr.SetValue(0, 2, 1.0);
00177
00178   rr.SetValue(1, 0, -0.5);
00179   rr.SetValue(1, 1, 0.5);
00180   rr.SetValue(1, 2, 1.5);
00181
00182   rr.SetValue(2, 0, 0.25);
00183   rr.SetValue(2, 1, 0.25);
00184   rr.SetValue(2, 2, 2.25);
00185
00186   rr.SetValue(3, 0, -0.125);
00187   rr.SetValue(3, 1, 0.125);
00188   rr.SetValue(3, 2, 3.375);
00189
00190   mtk::Tools::EndUnitTestNo(6);
00191   mtk::Tools::Assert(m7 == rr);
00192 }
00193
00194 void TestKron() {
00195
00196   mtk::Tools::BeginUnitTestNo(7);
00197
00198   bool padded = false;
00199   bool transpose = false;
00200   int lots_of_rows = 2;
00201   int lots_of_cols = 5;
00202   mtk::DenseMatrix m8(lots_of_rows,padded,transpose);
00203
00204   mtk::DenseMatrix m9(lots_of_rows,lots_of_cols);
00205
00206   for (auto ii = 0; ii < lots_of_rows; ++ii) {
00207     for (auto jj = 0; jj < lots_of_cols; ++jj) {
00208       m9.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00209     }
00210   }
00211
00212   mtk::DenseMatrix m10 = mtk::DenseMatrix::Kron(m8,m9);
00213
00214   mtk::DenseMatrix rr(lots_of_rows*lots_of_rows, lots_of_rows*lots_of_cols);
00215
00216   rr.SetValue(0,0,1.0);
00217   rr.SetValue(0,1,2.0);
00218   rr.SetValue(0,2,3.0);
00219   rr.SetValue(0,3,4.0);
00220   rr.SetValue(0,4,5.0);
00221   rr.SetValue(0,5,0.0);
00222   rr.SetValue(0,6,0.0);
00223   rr.SetValue(0,7,0.0);
00224   rr.SetValue(0,8,0.0);
00225   rr.SetValue(0,9,0.0);
00226
00227   rr.SetValue(1,0,6.0);
00228   rr.SetValue(1,1,7.0);
00229   rr.SetValue(1,2,8.0);
00230   rr.SetValue(1,3,9.0);
00231   rr.SetValue(1,4,10.0);
00232   rr.SetValue(1,5,0.0);
00233   rr.SetValue(1,6,0.0);
00234   rr.SetValue(1,7,0.0);
00235   rr.SetValue(1,8,0.0);
00236   rr.SetValue(1,9,0.0);
00237
00238   rr.SetValue(2,0,0.0);
00239   rr.SetValue(2,1,0.0);
00240   rr.SetValue(2,2,0.0);
00241   rr.SetValue(2,3,0.0);
00242   rr.SetValue(2,4,0.0);
00243   rr.SetValue(2,5,1.0);
00244   rr.SetValue(2,6,2.0);
00245   rr.SetValue(2,7,3.0);
00246   rr.SetValue(2,8,4.0);
```

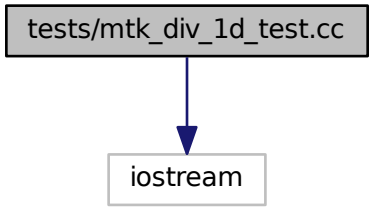
```
00247   rr.SetValue(2,9,5.0);
00248
00249   rr.SetValue(3,0,0.0);
00250   rr.SetValue(3,1,0.0);
00251   rr.SetValue(3,2,0.0);
00252   rr.SetValue(3,3,0.0);
00253   rr.SetValue(3,4,0.0);
00254   rr.SetValue(3,5,6.0);
00255   rr.SetValue(3,6,7.0);
00256   rr.SetValue(3,7,8.0);
00257   rr.SetValue(3,8,9.0);
00258   rr.SetValue(3,9,10.0);
00259
00260   mtk::Tools::EndUnitTestNo(7);
00261   mtk::Tools::Assert(m10 == rr);
00262 }
00263
00264 void TestConstructWithNumRowsNumColsAssignmentOperator() {
00265
00266   mtk::Tools::BeginUnitTestNo(8);
00267
00268   int lots_of_rows = 4;
00269   int lots_of_cols = 3;
00270   mtk::DenseMatrix m11(lots_of_rows,lots_of_cols);
00271
00272   for (auto ii = 0; ii < lots_of_rows; ++ii) {
00273     for (auto jj = 0; jj < lots_of_cols; ++jj) {
00274       m11.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00275     }
00276   }
00277
00278   m11.Transpose();
00279
00280   mtk::DenseMatrix m12;
00281
00282   m12 = m11;
00283
00284   mtk::Tools::EndUnitTestNo(8);
00285   mtk::Tools::Assert(m11 == m12);
00286 }
00287
00288 void TestConstructAsVandermondeTransposeAssignmentOperator() {
00289
00290   mtk::Tools::BeginUnitTestNo(9);
00291
00292   bool transpose = false;
00293   int gg_l = 3;
00294   int progression_length = 4;
00295   mtk::Real gg[] = {-0.5, 0.5, 1.5};
00296
00297   mtk::DenseMatrix m13(gg, gg_l ,progression_length, transpose);
00298
00299   mtk::DenseMatrix m14;
00300
00301   m14 = m13;
00302
00303   m13.Transpose();
00304
00305   m14 = m13;
00306
00307   mtk::Tools::EndUnitTestNo(9);
00308   mtk::Tools::Assert(m13 == m14);
00309 }
00310
00311 int main () {
00312
00313   std::cout << "Testing mtk::DenseMatrix class." << std::endl;
00314
00315   TestDefaultConstructor();
00316   TestConstructorWithNumRowsNumCols();
00317   TestConstructAsIdentity();
00318   TestConstructAsVandermonde();
00319   TestSetValueGetValue();
00320   TestConstructAsVandermondeTranspose();
00321   TestKron();
00322   TestConstructWithNumRowsNumColsAssignmentOperator();
00323   TestConstructAsVandermondeTransposeAssignmentOperator();
00324 }
00325
00326 #else
00327 #include <iostream>
```

```
00328 using std::cout;
00329 using std::endl;
00330 int main () {
00331   cout << "This code HAS to be compiled with support for C++11." << endl;
00332   cout << "Exiting..." << endl;
00333 }
00334 #endif
```

## 17.111 tests/mtk_div_1d_test.cc File Reference

Testing the mimetic 1D divergence, constructed with the CBS algorithm.

`#include <iostream>`
Include dependency graph for mtk_div_1d_test.cc:




### Functions

- int main ()

### 17.111.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_1d_test.cc.

### 17.111.2 Function Documentation

#### 17.111.2.1 int main ( )

Definition at line 288 of file mtk_div_1d_test.cc.

## 17.112 mtk_div_1d_test.cc

```
00001
```

```
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
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00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Div1D div2;
00065
00066   bool assertion = div2.ConstructDiv1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00070   }
00071
00072   mtk::Tools::EndUnitTestNo(1);
00073   mtk::Tools::Assert(assertion);
00074 }
00075
00076 void TestDefaultConstructorFactoryMethodFourthOrder() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Div1D div4;
00081
00082   bool assertion = div4.ConstructDiv1D(4);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(2);
```

```
00089   mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestDefaultConstructorFactoryMethodSixthOrder() {
00093
00094   mtk::Tools::BeginUnitTestNo(3);
00095
00096   mtk::Div1D div6;
00097
00098   bool assertion = div6.ConstructDiv1D(6);
00099
00100   if (!assertion) {
00101     std::cerr << "Mimetic div (6th order) could not be built." << std::endl;
00102   }
00103
00104   mtk::Tools::EndUnitTestNo(3);
00105   mtk::Tools::Assert(assertion);
00106 }
00107
00108 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00109
00110   mtk::Tools::BeginUnitTestNo(4);
00111
00112   mtk::Div1D div8;
00113
00114   bool assertion = div8.ConstructDiv1D(8);
00115
00116   if (!assertion) {
00117     std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00118   }
00119
00120   mtk::Tools::EndUnitTestNo(4);
00121   mtk::Tools::Assert(assertion);
00122 }
00123
00124 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00125
00126   mtk::Tools::BeginUnitTestNo(5);
00127
00128   mtk::Div1D div10;
00129
00130   bool assertion = div10.ConstructDiv1D(10);
00131
00132   if (!assertion) {
00133     std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00134   }
00135
00136   mtk::Tools::EndUnitTestNo(5);
00137   mtk::Tools::Assert(assertion);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142   mtk::Tools::BeginUnitTestNo(6);
00143
00144   mtk::Div1D div12;
00145
00146   bool assertion = div12.ConstructDiv1D(12);
00147
00148   if (!assertion) {
00149     std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00150   }
00151
00152   mtk::Tools::EndUnitTestNo(6);
00153   mtk::Tools::Assert(assertion);
00154 }
00155
00156 void TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold() {
00157
00158   mtk::Tools::BeginUnitTestNo(7);
00159
00160   mtk::Div1D div14;
00161
00162   bool assertion = div14.ConstructDiv1D(14);
00163
00164   if (!assertion) {
00165     std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00166   }
00167
00168   mtk::Tools::EndUnitTestNo(7);
00169   mtk::Tools::Assert(assertion);
```

```
00170 }
00171
00172 void TestSecondOrderReturnAsDenseMatrixWithGrid() {
00173
00174   mtk::Tools::BeginUnitTestNo(8);
00175
00176   mtk::Div1D div2;
00177
00178   bool assertion = div2.ConstructDiv1D();
00179
00180   if (!assertion) {
00181     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00182   }
00183
00184   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00185
00186   mtk::DenseMatrix div2m(div2.ReturnAsDenseMatrix(grid));
00187
00188   int rr{7};
00189   int cc{6};
00190
00191   mtk::DenseMatrix ref(rr, cc);
00192
00193   // Row 2.
00194   ref.SetValue(1,0,-5.0);
00195   ref.SetValue(1,1,5.0);
00196   ref.SetValue(1,2,0.0);
00197   ref.SetValue(1,3,0.0);
00198   ref.SetValue(1,4,0.0);
00199   ref.SetValue(1,5,0.0);
00200   ref.SetValue(1,6,0.0);
00201
00202   // Row 3.
00203   ref.SetValue(2,0,0.0);
00204   ref.SetValue(2,1,-5.0);
00205   ref.SetValue(2,2,5.0);
00206   ref.SetValue(2,3,0.0);
00207   ref.SetValue(2,4,0.0);
00208   ref.SetValue(2,5,0.0);
00209   ref.SetValue(2,6,0.0);
00210
00211   // Row 4.
00212   ref.SetValue(3,0,0.0);
00213   ref.SetValue(3,1,0.0);
00214   ref.SetValue(3,2,-5.0);
00215   ref.SetValue(3,3,5.0);
00216   ref.SetValue(3,4,0.0);
00217   ref.SetValue(3,5,0.0);
00218   ref.SetValue(3,6,0.0);
00219
00220   // Row 5.
00221   ref.SetValue(4,0,0.0);
00222   ref.SetValue(4,1,0.0);
00223   ref.SetValue(4,2,0.0);
00224   ref.SetValue(4,3,-5.0);
00225   ref.SetValue(4,4,5.0);
00226   ref.SetValue(4,5,0.0);
00227   ref.SetValue(4,6,0.0);
00228
00229   // Row 6.
00230   ref.SetValue(5,0,0.0);
00231   ref.SetValue(5,1,0.0);
00232   ref.SetValue(5,2,0.0);
00233   ref.SetValue(5,3,0.0);
00234   ref.SetValue(5,4,-5.0);
00235   ref.SetValue(5,5,5.0);
00236   ref.SetValue(5,6,0.0);
00237
00238   assertion = assertion && (div2m == ref);
00239
00240   mtk::Tools::EndUnitTestNo(8);
00241   mtk::Tools::Assert(assertion);
00242 }
00243
00244 void TestFourthOrderReturnAsDenseMatrixWithGrid() {
00245
00246   mtk::Tools::BeginUnitTestNo(9);
00247
00248   mtk::Div1D div4;
00249
00250   bool assertion = div4.ConstructDiv1D(4);
```

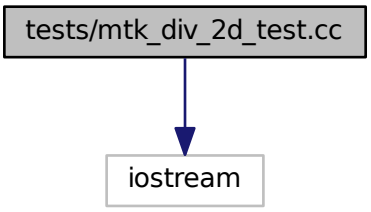
```
00251
00252   if (!assertion) {
00253     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00254   }
00255
00256   std::cout << div4 << std::endl;
00257
00258   mtk::UniStgGrid1D grid(0.0, 1.0, 11);
00259
00260   std::cout << grid << std::endl;
00261
00262   mtk::DenseMatrix div4m(div4.ReturnAsDenseMatrix(grid));
00263
00264   std::cout << div4m << std::endl;
00265
00266   mtk::Tools::EndUnitTestNo(9);
00267 }
00268
00269 int main () {
00270
00271   std::cout << "Testing mtk::Div1D class." << std::endl;
00272
00273   TestDefaultConstructorFactoryMethodDefault();
00274   TestDefaultConstructorFactoryMethodFourthOrder();
00275   TestDefaultConstructorFactoryMethodSixthOrder();
00276   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00277   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00278   TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00279   TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold();
00280   TestSecondOrderReturnAsDenseMatrixWithGrid();
00281   TestFourthOrderReturnAsDenseMatrixWithGrid();
00282 }
00283
00284 #else
00285 #include <iostream>
00286 using std::cout;
00287 using std::endl;
00288 int main () {
00289   cout << "This code HAS to be compiled with support for C++11." << endl;
00290   cout << "Exiting..." << endl;
00291 }
00292 #endif
```

## 17.113 tests/mtk_div_2d_test.cc File Reference

Test file for the mtk::Div2D class.

`#include <iostream>`

Include dependency graph for mtk_div_2d_test.cc:



### Functions

- int main ()

### 17.113.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_div_2d_test.cc.

### 17.113.2 Function Documentation

#### 17.113.2.1 int main ( )

Definition at line 139 of file mtk_div_2d_test.cc.

## 17.114 mtk_div_2d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

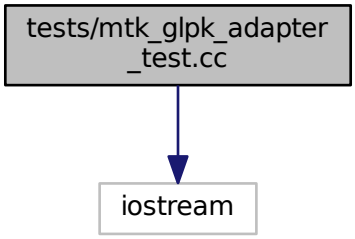
```
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Div2D dd;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real ee = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00078
00079   bool assertion = dd.ConstructDiv2D(ddg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Div2D dd;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real ee = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00104
00105   bool assertion = dd.ConstructDiv2D(ddg);
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (ddm.num_rows() != mtk::kZero);
00114
00115   std::cout << ddm << std::endl;
00116
00117   assertion = assertion && ddm.WriteToFile("mtk_div_2d_test_02.dat");
00118
00119   if(!assertion) {
00120     std::cerr << "Error writing to file." << std::endl;
00121   }
00122
00123   mtk::Tools::EndUnitTestNo(2);
00124   mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129   std::cout << "Testing mtk::Div2D class." << std::endl;
00130
00131   TestDefaultConstructorFactory();
00132   TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
```

```
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140   cout << "This code HAS to be compiled with support for C++11." << endl;
00141   cout << "Exiting..." << endl;
00142 }
00143 #endif
```

## 17.115 tests/mtk_glpk_adapter_test.cc File Reference

Test file for the mtk::GLPKAdapter class.

`#include <iostream>`
Include dependency graph for mtk_glpk_adapter_test.cc:




### Functions

- int main ()

### 17.115.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Test the mtk::GLPKAdapter class.

Definition in file mtk_glpk_adapter_test.cc.

### 17.115.2 Function Documentation

#### 17.115.2.1 int main ( )

Definition at line 81 of file mtk_glpk_adapter_test.cc.

# 17.116 mtk_glpk_adapter_test.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
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00037
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00043
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072   std::cout << "Testing mtk::GLPKAdapter class." << std::endl;
00073
00074   Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082   cout << "This code HAS to be compiled with support for C++11." << endl;
00083   cout << "Exiting..." << endl;
00084 }
00085 #endif
```
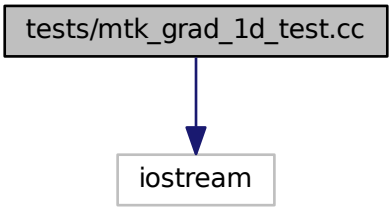

## 17.117 tests/mtk_grad_1d_test.cc File Reference

Testing the mimetic 1D gradient, constructed with the CBS algorithm.

```
#include <iostream>
```

Include dependency graph for mtk_grad_1d_test.cc:




### Functions

- int main ()

### 17.117.1 Detailed Description

**Author**

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Definition in file mtk_grad_1d_test.cc.

### 17.117.2 Function Documentation

#### 17.117.2.1 int main ( )

Definition at line 319 of file mtk_grad_1d_test.cc.

## 17.118 mtk_grad_1d_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
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00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
```

```
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Grad1D grad2;
00065
00066   bool assertion = grad2.ConstructGrad1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00070
00071   }
00072
00073   std::cout << grad2 << std::endl;
00074
00075   mtk::Tools::EndUnitTestNo(1);
00076   mtk::Tools::Assert(assertion);
00077 }
00078
00079 void TestDefaultConstructorFactoryMethodFourthOrder() {
00080
00081   mtk::Tools::BeginUnitTestNo(2);
00082
00083   mtk::Grad1D grad4;
00084
00085   bool assertion = grad4.ConstructGrad1D(4);
00086
00087   if (!assertion) {
00088     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00089   }
00090
00091   std::cout << grad4 << std::endl;
00092
00093   mtk::Tools::EndUnitTestNo(2);
00094   mtk::Tools::Assert(assertion);
00095 }
00096
00097 void TestDefaultConstructorFactoryMethodSixthOrder() {
00098
00099   mtk::Tools::BeginUnitTestNo(3);
```

```
00100
00101   mtk::Grad1D grad6;
00102
00103   bool assertion = grad6.ConstructGrad1D(6);
00104
00105   if (!assertion) {
00106     std::cerr << "Mimetic grad (6th order) could not be built." << std::endl;
00107   }
00108
00109   std::cout << grad6 << std::endl;
00110
00111   mtk::Tools::EndUnitTestNo(3);
00112   mtk::Tools::Assert(assertion);
00113 }
00114
00115 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00116
00117   mtk::Tools::BeginUnitTestNo(4);
00118
00119   mtk::Grad1D grad8;
00120
00121   bool assertion = grad8.ConstructGrad1D(8);
00122
00123   if (!assertion) {
00124     std::cerr << "Mimetic grad (8th order) could not be built." << std::endl;
00125   }
00126
00127   std::cout << grad8 << std::endl;
00128
00129   mtk::Tools::EndUnitTestNo(4);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00134
00135   mtk::Tools::BeginUnitTestNo(5);
00136
00137   mtk::Grad1D grad10;
00138
00139   bool assertion = grad10.ConstructGrad1D(10);
00140
00141   if (!assertion) {
00142     std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00143   }
00144
00145   std::cout << grad10 << std::endl;
00146
00147   mtk::Tools::EndUnitTestNo(5);
00148   mtk::Tools::Assert(assertion);
00149 }
00150
00151 void TestReturnAsDenseMatrixWithGrid() {
00152
00153   mtk::Tools::BeginUnitTestNo(6);
00154
00155   mtk::Grad1D grad2;
00156
00157   bool assertion = grad2.ConstructGrad1D();
00158
00159   if (!assertion) {
00160     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00161   }
00162
00163   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00164
00165   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00166
00167   int rr{6};
00168   int cc{7};
00169
00170   mtk::DenseMatrix ref(rr, cc);
00171
00172   // Row 1.
00173   ref.SetValue(0,0,-13.3333);
00174   ref.SetValue(0,1,15);
00175   ref.SetValue(0,2,-1.66667);
00176   ref.SetValue(0,3,0.0);
00177   ref.SetValue(0,4,0.0);
00178   ref.SetValue(0,5,0.0);
00179   ref.SetValue(0,6,0.0);
00180
```

```
00181   // Row 2.
00182   ref.SetValue(1,0,0.0);
00183   ref.SetValue(1,1,-5.0);
00184   ref.SetValue(1,2,5.0);
00185   ref.SetValue(1,3,0.0);
00186   ref.SetValue(1,4,0.0);
00187   ref.SetValue(1,5,0.0);
00188   ref.SetValue(1,6,0.0);
00189
00190   // Row 3.
00191   ref.SetValue(2,0,0.0);
00192   ref.SetValue(2,1,0.0);
00193   ref.SetValue(2,2,-5.0);
00194   ref.SetValue(2,3,5.0);
00195   ref.SetValue(2,4,0.0);
00196   ref.SetValue(2,5,0.0);
00197   ref.SetValue(2,6,0.0);
00198
00199   // Row 4.
00200   ref.SetValue(3,0,0.0);
00201   ref.SetValue(3,1,0.0);
00202   ref.SetValue(3,2,0.0);
00203   ref.SetValue(3,3,-5.0);
00204   ref.SetValue(3,4,5.0);
00205   ref.SetValue(3,5,0.0);
00206   ref.SetValue(3,6,0.0);
00207
00208   // Row 5.
00209   ref.SetValue(4,0,0.0);
00210   ref.SetValue(4,1,0.0);
00211   ref.SetValue(4,2,0.0);
00212   ref.SetValue(4,3,0.0);
00213   ref.SetValue(4,4,-5.0);
00214   ref.SetValue(4,5,5.0);
00215   ref.SetValue(4,6,0.0);
00216
00217   // Row 6.
00218   ref.SetValue(5,0,0.0);
00219   ref.SetValue(5,1,0.0);
00220   ref.SetValue(5,2,0.0);
00221   ref.SetValue(5,3,0.0);
00222   ref.SetValue(5,4,1.66667);
00223   ref.SetValue(5,5,-15.0);
00224   ref.SetValue(5,6,13.3333);
00225
00226   mtk::Tools::EndUnitTestNo(6);
00227   mtk::Tools::Assert(grad2m == ref);
00228 }
00229
00230 void TestReturnAsDimensionlessDenseMatrix() {
00231
00232   mtk::Tools::BeginUnitTestNo(7);
00233
00234   mtk::Grad1D grad4;
00235
00236   bool assertion = grad4.ConstructGrad1D(4);
00237
00238   if (!assertion) {
00239     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00240   }
00241
00242   mtk::DenseMatrix grad4m(grad4.ReturnAsDimensionlessDenseMatrix
      (10));
00243
00244   std::cout << grad4m << std::endl;
00245
00246   mtk::Tools::EndUnitTestNo(7);
00247   mtk::Tools::Assert(assertion);
00248 }
00249
00250 void TestWriteToFile() {
00251
00252   mtk::Tools::BeginUnitTestNo(8);
00253
00254   mtk::Grad1D grad2;
00255
00256   bool assertion = grad2.ConstructGrad1D();
00257
00258   if (!assertion) {
00259     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00260   }
```

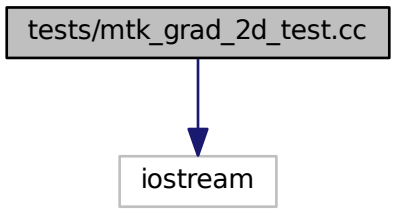
```
00261
00262   mtk::UniStgGrid1D grid(0.0, 1.0, 50);
00263
00264   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00265
00266   std::cout << grad2m << std::endl;
00267
00268   assertion = assertion && grad2m.WriteToFile("mtk_grad_1d_test_08.dat");
00269
00270   if(!assertion) {
00271     std::cerr << "Error writing to file." << std::endl;
00272   }
00273
00274   mtk::Tools::EndUnitTestNo(8);
00275   mtk::Tools::Assert(assertion);
00276 }
00277
00278 void TestMimBndy() {
00279
00280   mtk::Tools::BeginUnitTestNo(9);
00281
00282   mtk::Grad1D grad2;
00283
00284   bool assertion = grad2.ConstructGrad1D();
00285
00286   if (!assertion) {
00287     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00288   }
00289
00290   std::cout << grad2 << std::endl;
00291
00292   mtk::DenseMatrix grad2m(grad2.mim_bndy());
00293
00294   std::cout << grad2m << std::endl;
00295
00296   mtk::Tools::EndUnitTestNo(9);
00297   mtk::Tools::Assert(assertion);
00298 }
00299
00300 int main () {
00301
00302   std::cout << "Testing mtk::Grad1D class." << std::endl;
00303
00304   TestDefaultConstructorFactoryMethodDefault();
00305   TestDefaultConstructorFactoryMethodFourthOrder();
00306   TestDefaultConstructorFactoryMethodSixthOrder();
00307   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00308   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00309   TestReturnAsDenseMatrixWithGrid();
00310   TestReturnAsDimensionlessDenseMatrix();
00311   TestWriteToFile();
00312   TestMimBndy();
00313 }
00314
00315 #else
00316 #include <iostream>
00317 using std::cout;
00318 using std::endl;
00319 int main () {
00320   cout << "This code HAS to be compiled with support for C++11." << endl;
00321   cout << "Exiting..." << endl;
00322 }
00323 #endif
```

## 17.119 tests/mtk_grad_2d_test.cc File Reference

Test file for the mtk::Grad2D class.

```
#include <iostream>
```

Include dependency graph for mtk_grad_2d_test.cc:




## Functions

- int main ()

### 17.119.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_2d_test.cc.

### 17.119.2 Function Documentation

#### 17.119.2.1 int main ( )

Definition at line 139 of file mtk_grad_2d_test.cc.

## 17.120 mtk_grad_2d_test.cc

```
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00008 /*
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00010 University. All rights reserved.
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00013 are permitted provided that the following conditions are met:
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00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00024 3. Redistributions in binary form must reproduce the above copyright notice,
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Grad2D gg;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00078
00079   bool assertion = gg.ConstructGrad2D(ggg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Grad2D gg;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real dd = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00104
00105   bool assertion = gg.ConstructGrad2D(ggg);
```
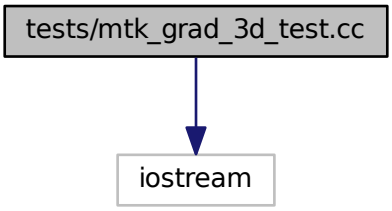

```
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (ggm.num_rows() != mtk::kZero);
00114
00115   std::cout << ggm << std::endl;
00116
00117   assertion = assertion && ggm.WriteToFile("mtk_grad_2d_test_02.dat");
00118
00119   if(!assertion) {
00120     std::cerr << "Error writing to file." << std::endl;
00121   }
00122
00123   mtk::Tools::EndUnitTestNo(2);
00124   mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129   std::cout << "Testing mtk::Grad2D class." << std::endl;
00130
00131   TestDefaultConstructorFactory();
00132   TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140   cout << "This code HAS to be compiled with support for C++11." << endl;
00141   cout << "Exiting..." << endl;
00142 }
00143 #endif
```

## 17.121 tests/mtk_grad_3d_test.cc File Reference

Test file for the mtk::Grad3D class.

`#include <iostream>`
Include dependency graph for mtk_grad_3d_test.cc:




### Functions

- int main ()

### 17.121.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_grad_3d_test.cc.

### 17.121.2 Function Documentation

#### 17.121.2.1 int main ( )

Definition at line 145 of file mtk_grad_3d_test.cc.

## 17.122 mtk_grad_3d_test.cc

```
00001
00008 /*
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
```

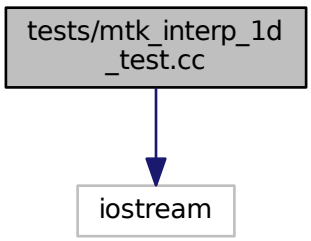
```
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Grad3D gg;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073   mtk::Real ee = 0.0;
00074   mtk::Real ff = 1.0;
00075
00076   int nn = 5;
00077   int mm = 5;
00078   int oo = 5;
00079
00080   mtk::UniStgGrid3D ggg(aa, bb, nn, cc, dd, mm, ee, ff, oo,
      mtk::VECTOR);
00081
00082   bool assertion = gg.ConstructGrad3D(ggg);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(1);
00089   mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestReturnAsDenseMatrixWriteToFile() {
00093
00094   mtk::Tools::BeginUnitTestNo(2);
00095
00096   mtk::Grad3D gg;
00097
00098   mtk::Real aa = 0.0;
00099   mtk::Real bb = 1.0;
00100   mtk::Real cc = 0.0;
00101   mtk::Real dd = 1.0;
00102   mtk::Real ee = 0.0;
00103   mtk::Real ff = 1.0;
00104
00105   int nn = 5;
00106   int mm = 5;
00107   int oo = 5;
00108
00109   mtk::UniStgGrid3D ggg(aa, bb, nn, cc, dd, mm, ee, ff, oo,
      mtk::VECTOR);
00110
00111   bool assertion = gg.ConstructGrad3D(ggg);
00112
00113   if (!assertion) {
00114     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00115   }
00116
00117   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00118
00119   assertion = assertion && (ggm.num_rows() != mtk::kZero);
00120
00121   std::cout << ggm << std::endl;
00122
00123   assertion = assertion && ggm.WriteToFile("mtk_grad_3d_test_02.dat");
00124
00125   if(!assertion) {
00126     std::cerr << "Error writing to file." << std::endl;
00127   }
00128
00129   mtk::Tools::EndUnitTestNo(2);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 int main () {
00134
00135   std::cout << "Testing mtk::Grad2D class." << std::endl;
00136
00137   TestDefaultConstructorFactory();
00138   TestReturnAsDenseMatrixWriteToFile();
00139 }
```

```
00140
00141 #else
00142 #include <iostream>
00143 using std::cout;
00144 using std::endl;
00145 int main () {
00146   cout << "This code HAS to be compiled with support for C++11." << endl;
00147   cout << "Exiting..." << endl;
00148 }
00149 #endif
```

## 17.123 tests/mtk_interp_1d_test.cc File Reference

Testing the 1D interpolation.

`#include <iostream>`
Include dependency graph for mtk_interp_1d_test.cc:




### Functions

- int main ()

### 17.123.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu
: Johnny Corbino - jcorbino at mail dot sdsu dot edu

Definition in file mtk_interp_1d_test.cc.

### 17.123.2 Function Documentation

#### 17.123.2.1 int main ( )

Definition at line 113 of file mtk_interp_1d_test.cc.

## 17.124 mtk_interp_1d_test.cc

```
00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
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00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
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00039 not infringe any patent, copyright, or any other intellectual property rights of
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064   mtk::Tools::BeginUnitTestNo(1);
00065
00066   mtk::Interp1D inter;
00067
00068   bool assertion = inter.ConstructInterp1D();
00069
00070   if (!assertion) {
00071     std::cerr << "Mimetic interp could not be built." << std::endl;
00072   }
00073
00074   mtk::Tools::EndUnitTestNo(1);
00075   mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestReturnAsDenseMatrixWithGrid() {
00079
00080   mtk::Tools::BeginUnitTestNo(2);
00081
00082   mtk::Interp1D inter;
00083
00084   bool assertion = inter.ConstructInterp1D();
00085
00086   if (!assertion) {
```

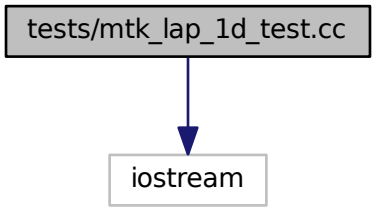
```
00087     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00088   }
00089
00090   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00091
00092   mtk::DenseMatrix interpm(inter.ReturnAsDenseMatrix(grid));
00093
00094   assertion =
00095     assertion && interpm.GetValue(0,0) == 1.0 && interpm.GetValue(5,6) == 1.0;
00096
00097   mtk::Tools::EndUnitTestNo(2);
00098   mtk::Tools::Assert(assertion);
00099 }
00100
00101 int main () {
00102
00103   std::cout << "Testing mtk::Interp1D class." << std::endl;
00104
00105   TestDefaultConstructorFactoryMethodDefault();
00106   TestReturnAsDenseMatrixWithGrid();
00107 }
00108
00109 #else
00110 #include <iostream>
00111 using std::cout;
00112 using std::endl;
00113 int main () {
00114   cout << "This code HAS to be compiled with support for C++11." << endl;
00115   cout << "Exiting..." << endl;
00116 }
00117 #endif
```

## 17.125 tests/mtk_lap_1d_test.cc File Reference

Testing the 1D Laplacian operator.

`#include <iostream>`

Include dependency graph for mtk_lap_1d_test.cc:




### Functions

- int main ()

### 17.125.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu
: Johnny Corbino - jcorbino at mail dot sdsu dot edu

Definition in file mtk_lap_1d_test.cc.

### 17.125.2 Function Documentation

#### 17.125.2.1 int main ( )

Definition at line 193 of file mtk_lap_1d_test.cc.

## 17.126 mtk_lap_1d_test.cc

```
00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
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00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
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00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064   mtk::Tools::BeginUnitTestNo(1);
```

```
00065
00066   mtk::Lap1D lap2;
00067
00068   bool assertion = lap2.ConstructLap1D();
00069
00070   if (!assertion) {
00071     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00072   }
00073
00074   mtk::Tools::EndUnitTestNo(1);
00075   mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestDefaultConstructorFactoryMethodFourthOrder() {
00079
00080   mtk::Tools::BeginUnitTestNo(2);
00081
00082   mtk::Lap1D lap4;
00083
00084   bool assertion = lap4.ConstructLap1D(4);
00085
00086   if (!assertion) {
00087     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00088   }
00089
00090   mtk::Tools::EndUnitTestNo(2);
00091   mtk::Tools::Assert(assertion);
00092 }
00093
00094 void TestDefaultConstructorFactoryMethodSixthOrder() {
00095
00096   mtk::Tools::BeginUnitTestNo(3);
00097
00098   mtk::Lap1D lap6;
00099
00100   bool assertion = lap6.ConstructLap1D(6);
00101
00102   if (!assertion) {
00103     std::cerr << "Mimetic lap (6th order) could not be built." << std::endl;
00104   }
00105
00106   mtk::Tools::EndUnitTestNo(3);
00107   mtk::Tools::Assert(assertion);
00108 }
00109
00110 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00111
00112   mtk::Tools::BeginUnitTestNo(4);
00113
00114   mtk::Lap1D lap8;
00115
00116   bool assertion = lap8.ConstructLap1D(8);
00117
00118   if (!assertion) {
00119     std::cerr << "Mimetic lap (8th order) could not be built." << std::endl;
00120   }
00121
00122   mtk::Tools::EndUnitTestNo(4);
00123 }
00124
00125 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00126
00127   mtk::Tools::BeginUnitTestNo(5);
00128
00129   mtk::Lap1D lap10;
00130
00131   bool assertion = lap10.ConstructLap1D(10);
00132
00133   if (!assertion) {
00134     std::cerr << "Mimetic lap (10th order) could not be built." << std::endl;
00135   }
00136
00137   mtk::Tools::EndUnitTestNo(5);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142   mtk::Tools::BeginUnitTestNo(6);
00143
00144   mtk::Lap1D lap12;
00145
```

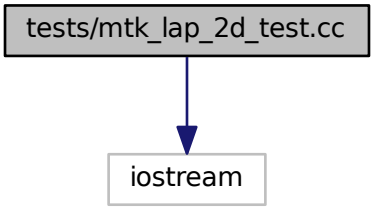
```
00146   bool assertion = lap12.ConstructLap1D(12);
00147
00148   if (!assertion) {
00149     std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00150   }
00151
00152   mtk::Tools::EndUnitTestNo(6);
00153 }
00154
00155 void TestReturnAsDenseMatrix() {
00156
00157   mtk::Tools::BeginUnitTestNo(8);
00158
00159   mtk::Lap1D lap4;
00160
00161   bool assertion = lap4.ConstructLap1D(4);
00162
00163   if (!assertion) {
00164     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00165   }
00166
00167   mtk::UniStgGrid1D aux(0.0, 1.0, 11);
00168
00169   mtk::DenseMatrix lap4_m(lap4.ReturnAsDenseMatrix(aux));
00170
00171   assertion = assertion &&
00172       abs(lap4_m.GetValue(1, 0) - 385.133) < mtk::kDefaultTolerance &&
00173       abs(lap4_m.GetValue(11, 12) - 385.133) < mtk::kDefaultTolerance;
00174   mtk::Tools::EndUnitTestNo(8);
00175   mtk::Tools::Assert(assertion);
00176 }
00177
00178 int main () {
00179
00180   std::cout << "Testing MTK 1D Laplacian" << std::endl;
00181
00182   TestDefaultConstructorFactoryMethodDefault();
00183   TestDefaultConstructorFactoryMethodFourthOrder();
00184   TestDefaultConstructorFactoryMethodSixthOrder();
00185   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00186   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00187   TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00188   TestReturnAsDenseMatrix();
00189 }
00190
00191 #else
00192 #include <iostream>
00193 int main () {
00194   std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00195   std::cout << "Exiting..." << std::endl;
00196 }
00197 #endif
```

## 17.127 tests/mtk_lap_2d_test.cc File Reference

Test file for the mtk::Lap2D class.

```
#include <iostream>
```

Include dependency graph for mtk_lap_2d_test.cc:




### Functions

- int main ()

### 17.127.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_lap_2d_test.cc.

### 17.127.2 Function Documentation

#### 17.127.2.1 int main ( )

Definition at line 139 of file mtk_lap_2d_test.cc.

## 17.128 mtk_lap_2d_test.cc

```
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00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
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00013 are permitted provided that the following conditions are met:
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00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
```

```
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
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00028 4. Usage of the binary form on proprietary applications shall require explicit
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00030 be given to the copyright holders.
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Lap2D ll;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00078
00079   bool assertion = ll.ConstructLap2D(llg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Lap2D ll;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real dd = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00104
00105   bool assertion = ll.ConstructLap2D(llg);
```
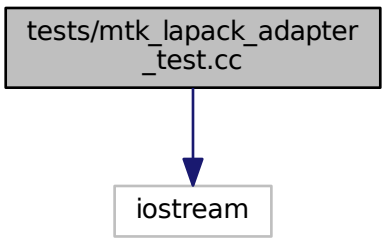

```
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (llm.num_rows() != 0);
00114
00115   std::cout << llm << std::endl;
00116
00117   assertion = assertion && llm.WriteToFile("mtk_lap_2d_test_02.dat");
00118
00119   if(!assertion) {
00120     std::cerr << "Error writing to file." << std::endl;
00121   }
00122
00123   mtk::Tools::EndUnitTestNo(2);
00124   mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129   std::cout << "Testing mtk::Lap2D class." << std::endl;
00130
00131   TestDefaultConstructorFactory();
00132   TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140   cout << "This code HAS to be compiled with support for C++11." << endl;
00141   cout << "Exiting..." << endl;
00142 }
00143 #endif
```

## 17.129 tests/mtk_lapack_adapter_test.cc File Reference

Test file for the mtk::LAPACKAdapter class.

`#include <iostream>`
Include dependency graph for mtk_lapack_adapter_test.cc:




### Functions

- int main ()

### 17.129.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Test the mtk::LAPACKAdapter class.

Definition in file mtk_lapack_adapter_test.cc.

### 17.129.2 Function Documentation

#### 17.129.2.1 int main ( )

Definition at line 81 of file mtk_lapack_adapter_test.cc.

## 17.130 mtk_lapack_adapter_test.cc

```
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
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00023 2. Redistributions of source code must be done through direct
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
```
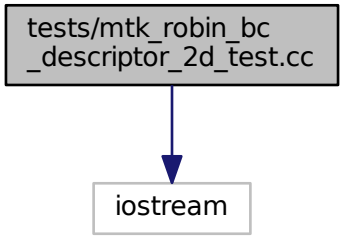

```
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072   std::cout << "Testing mtk::LAPACKAdapter class." << std::endl;
00073
00074   Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082   cout << "This code HAS to be compiled with support for C++11." << endl;
00083   cout << "Exiting..." << endl;
00084 }
00085 #endif
```

## 17.131 tests/mtk_robin_bc_descriptor_2d_test.cc File Reference

Test file for the mtk::RobinBCDescriptor2D class.

`#include <iostream>`
Include dependency graph for mtk_robin_bc_descriptor_2d_test.cc:




### Functions

- int main ()

### 17.131.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_robin_bc_descriptor_2d_test.cc.

### 17.131.2 Function Documentation

#### 17.131.2.1 int main ( )

Definition at line 198 of file mtk_robin_bc_descriptor_2d_test.cc.

## 17.132 mtk_robin_bc_descriptor_2d_test.cc

```
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00008 /*
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorGetters() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::RobinBCDescriptor2D bcd;
00068
00069   bool assertion{true};
00070
00071   assertion = assertion && bcd.highest_order_diff_west() == -1;
00072   assertion = assertion && bcd.highest_order_diff_east() == -1;
00073   assertion = assertion && bcd.highest_order_diff_south() == -1;
```

```
00074   assertion = assertion && bcd.highest_order_diff_north() == -1;
00075
00076   mtk::Tools::EndUnitTestNo(1);
00077   mtk::Tools::Assert(assertion);
00078 }
00079
00080 mtk::Real cc(const mtk::Real &xx, const mtk::Real &yy) {
00081
00082   return mtk::kOne;
00083 }
00084
00085 void TestPushBackImposeOnLaplacianMatrix() {
00086
00087   mtk::Tools::BeginUnitTestNo(2);
00088
00089   mtk::RobinBCDescriptor2D bcd;
00090
00091   bool assertion{true};
00092
00093   bcd.PushBackWestCoeff(cc);
00094   bcd.PushBackEastCoeff(cc);
00095   bcd.PushBackSouthCoeff(cc);
00096   bcd.PushBackNorthCoeff(cc);
00097
00098   assertion = assertion && bcd.highest_order_diff_west() == 0;
00099   assertion = assertion && bcd.highest_order_diff_east() == 0;
00100   assertion = assertion && bcd.highest_order_diff_south() == 0;
00101   assertion = assertion && bcd.highest_order_diff_north() == 0;
00102
00103   mtk::Real aa = 0.0;
00104   mtk::Real bb = 1.0;
00105   mtk::Real cc = 0.0;
00106   mtk::Real dd = 1.0;
00107
00108   int nn = 5;
00109   int mm = 5;
00110
00111   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00112
00113   mtk::Lap2D ll;
00114
00115   assertion = ll.ConstructLap2D(llg);
00116
00117   if (!assertion) {
00118     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00119   }
00120
00121   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00122
00123   assertion = assertion && (llm.num_rows() != 0);
00124
00125   bcd.ImposeOnLaplacianMatrix(ll, llg, llm);
00126
00127   assertion = assertion &&
00128     llm.WriteToFile("mtk_robin_bc_descriptor_2d_test_02.dat");
00129
00130   mtk::Tools::EndUnitTestNo(2);
00131   mtk::Tools::Assert(assertion);
00132 }
00133
00134 mtk::Real ScalarField(const mtk::Real &xx, const mtk::Real &yy) {
00135
00136   mtk::Real aux{-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy};
00137
00138   return xx*yy*exp(aux);
00139 }
00140
00141 mtk::Real HomogeneousDiricheletBC(const mtk::Real &xx,
00142                                   const mtk::Real &tt) {
00143
00144   return mtk::kZero;
00145 }
00146
00147 void TestImposeOnGrid() {
00148
00149   mtk::Tools::BeginUnitTestNo(3);
00150
00151   mtk::Real aa = 0.0;
00152   mtk::Real bb = 1.0;
00153   mtk::Real cc = 0.0;
00154   mtk::Real dd = 1.0;
```

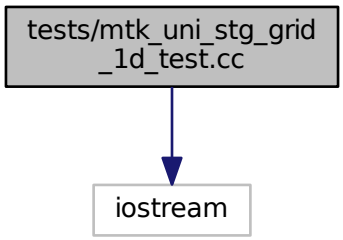
```
00155
00156   int nn = 5;
00157   int mm = 5;
00158
00159   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00160
00161   gg.BindScalarField(ScalarField);
00162
00163   mtk::RobinBCDescriptor2D desc;
00164
00165   desc.set_west_condition(HomogeneousDiricheletBC);
00166   desc.set_east_condition(HomogeneousDiricheletBC);
00167   desc.set_south_condition(HomogeneousDiricheletBC);
00168   desc.set_north_condition(HomogeneousDiricheletBC);
00169
00170   desc.ImposeOnGrid(gg);
00171
00172   bool assertion{gg.WriteToFile("mtk_robin_bc_descriptor_2d_test_03.dat",
00173                                 "x",
00174                                 "y",
00175                                 "u(x,y)")};
00176
00177   if(!assertion) {
00178     std::cerr << "Error writing to file." << std::endl;
00179   }
00180
00181   mtk::Tools::EndUnitTestNo(3);
00182   mtk::Tools::Assert(assertion);
00183 }
00184
00185 int main () {
00186
00187   std::cout << "Testing mtk::RobinBCDescriptor2D class." << std::endl;
00188
00189   TestDefaultConstructorGetters();
00190   TestPushBackImposeOnLaplacianMatrix();
00191   TestImposeOnGrid();
00192 }
00193
00194 #else
00195 #include <iostream>
00196 using std::cout;
00197 using std::endl;
00198 int main () {
00199   cout << "This code HAS to be compiled with support for C++11." << endl;
00200   cout << "Exiting..." << endl;
00201 }
00202 #endif
```

## 17.133 tests/mtk_uni_stg_grid_1d_test.cc File Reference

Test file for the mtk::UniStgGrid1D class.

```
#include <iostream>
```

Include dependency graph for mtk_uni_stg_grid_1d_test.cc:




## Functions

- int main ()

### 17.133.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_uni_stg_grid_1d_test.cc.

### 17.133.2 Function Documentation

#### 17.133.2.1 int main ( )

Definition at line 172 of file mtk_uni_stg_grid_1d_test.cc.

## 17.134 mtk_uni_stg_grid_1d_test.cc

```
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00013 are permitted provided that the following conditions are met:
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructor() {
00062
00063   mtk::Tools::BeginUnitTestNo(1);
00064
00065   mtk::UniStgGrid1D gg;
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068   mtk::Tools::Assert(gg.delta_x() == mtk::kZero);
00069 }
00070
00071 mtk::Real ScalarField(const mtk::Real &xx) {
00072
00073   return 2.0*xx;
00074 }
00075
00076 void TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Real aa = 0.0;
00081   mtk::Real bb = 1.0;
00082
00083   int nn = 5;
00084
00085   mtk::UniStgGrid1D gg(aa, bb, nn);
00086
00087   gg.BindScalarField(ScalarField);
00088
00089   std::cout << gg << std::endl;
00090
00091   mtk::Tools::EndUnitTestNo(2);
00092   mtk::Tools::Assert(gg.delta_x() == 0.2 && gg.
      num_cells_x() == 5);
00093 }
00094
00095 void TestBindScalarFieldWriteToFile() {
00096
00097   mtk::Tools::BeginUnitTestNo(3);
00098
00099   mtk::Real aa = 0.0;
00100   mtk::Real bb = 1.0;
00101
00102   int nn = 5;
00103
```

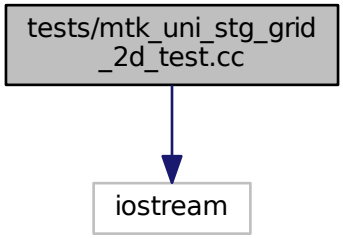
```
00104   mtk::UniStgGrid1D gg(aa, bb, nn);
00105
00106   bool assertion{true};
00107
00108   gg.BindScalarField(ScalarField);
00109
00110   assertion =
00111     assertion &&
00112     gg.discrete_field()[0] == 0.0 &&
00113     gg.discrete_field()[gg.num_cells_x() + 2 - 1] == 2.0;
00114
00115   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_03.dat", "x", "u(x)")) {
00116     std::cerr << "Error writing to file." << std::endl;
00117     assertion = false;
00118   }
00119
00120   mtk::Tools::EndUnitTestNo(3);
00121   mtk::Tools::Assert(assertion);
00122 }
00123
00124 mtk::Real VectorFieldPComponent(mtk::Real xx) {
00125
00126   return xx*xx;
00127 }
00128
00129 void TestBindVectorField() {
00130
00131   mtk::Tools::BeginUnitTestNo(4);
00132
00133   mtk::Real aa = 0.0;
00134   mtk::Real bb = 1.0;
00135
00136   int nn = 20;
00137
00138   mtk::UniStgGrid1D gg(aa, bb, nn, mtk::VECTOR);
00139
00140   bool assertion{true};
00141
00142   gg.BindVectorField(VectorFieldPComponent);
00143
00144   assertion =
00145     assertion &&
00146     gg.discrete_field()[0] == 0.0 &&
00147     gg.discrete_field()[gg.num_cells_x() + 1 - 1] == 1.0;
00148
00149   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_04.dat", "x", "v(x)")) {
00150     std::cerr << "Error writing to file." << std::endl;
00151     assertion = false;
00152   }
00153
00154   mtk::Tools::EndUnitTestNo(4);
00155   mtk::Tools::Assert(assertion);
00156 }
00157
00158 int main () {
00159
00160   std::cout << "Testing mtk::UniStgGrid1D class." << std::endl;
00161
00162   TestDefaultConstructor();
00163   TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField();
00164   TestBindScalarFieldWriteToFile();
00165   TestBindVectorField();
00166 }
00167
00168 #else
00169 #include <iostream>
00170 using std::cout;
00171 using std::endl;
00172 int main () {
00173   cout << "This code HAS to be compiled with support for C++11." << endl;
00174   cout << "Exiting..." << endl;
00175 }
00176 #endif
```

## 17.135 tests/mtk_uni_stg_grid_2d_test.cc File Reference

Test file for the mtk::UniStgGrid2D class.

```
#include <iostream>
```

Include dependency graph for mtk_uni_stg_grid_2d_test.cc:




### Functions

- int main ()

### 17.135.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file mtk_uni_stg_grid_2d_test.cc.

### 17.135.2 Function Documentation

#### 17.135.2.1 int main ( )

Definition at line 202 of file mtk_uni_stg_grid_2d_test.cc.

## 17.136 mtk_uni_stg_grid_2d_test.cc

```
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```
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00019 should be developed and included in any deliverable.
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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructor() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::UniStgGrid2D gg;
00068
00069   mtk::Tools::EndUnitTestNo(1);
00070   mtk::Tools::Assert(gg.delta_x() == mtk::kZero && gg.
      delta_y() == mtk::kZero);
00071 }
00072
00073 void
00074 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator() {
00075
00076   mtk::Tools::BeginUnitTestNo(2);
00077
00078   mtk::Real aa = 0.0;
00079   mtk::Real bb = 1.0;
00080   mtk::Real cc = 0.0;
00081   mtk::Real dd = 1.0;
00082
00083   int nn = 5;
00084   int mm = 7;
00085
00086   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00087
00088   std::cout << gg << std::endl;
00089
00090   mtk::Tools::EndUnitTestNo(2);
00091   mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00092                      abs(gg.delta_y() - 0.142857) <
      mtk::kDefaultTolerance);
00093 }
00094
00095 void TestGetters() {
00096
```

```
00097   mtk::Tools::BeginUnitTestNo(3);
00098
00099   mtk::Real aa = 0.0;
00100   mtk::Real bb = 1.0;
00101   mtk::Real cc = 0.0;
00102   mtk::Real dd = 1.0;
00103
00104   int nn = 5;
00105   int mm = 7;
00106
00107   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00108
00109   bool assertion{true};
00110
00111   assertion = assertion && (gg.west_bndy() == aa);
00112   assertion = assertion && (gg.east_bndy() == bb);
00113   assertion = assertion && (gg.num_cells_x() == nn);
00114   assertion = assertion && (gg.south_bndy() == cc);
00115   assertion = assertion && (gg.north_bndy() == dd);
00116   assertion = assertion && (gg.num_cells_y() == mm);
00117
00118   mtk::Tools::EndUnitTestNo(3);
00119   mtk::Tools::Assert(assertion);
00120 }
00121
00122 mtk::Real ScalarField(const mtk::Real &xx, const mtk::Real &yy) {
00123
00124   mtk::Real aux{-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy};
00125
00126   return xx*yy*exp(aux);
00127 }
00128
00129 void TestBindScalarFieldWriteToFile() {
00130
00131   mtk::Tools::BeginUnitTestNo(4);
00132
00133   mtk::Real aa = 0.0;
00134   mtk::Real bb = 1.0;
00135   mtk::Real cc = 0.0;
00136   mtk::Real dd = 1.0;
00137
00138   int nn = 5;
00139   int mm = 5;
00140
00141   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00142
00143   gg.BindScalarField(ScalarField);
00144
00145   if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_04.dat", "x", "y", "u(x,y)")) {
00146     std::cerr << "Error writing to file." << std::endl;
00147   }
00148
00149   mtk::Tools::EndUnitTestNo(4);
00150 }
00151
00152 mtk::Real VectorFieldPComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00153
00154   return xx + 0.01;
00155 }
00156
00157 mtk::Real VectorFieldQComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00158
00159   return yy + 0.01;
00160 }
00161
00162 void TestBindVectorField() {
00163
00164   mtk::Tools::BeginUnitTestNo(5);
00165
00166   mtk::Real aa = 0.0;
00167   mtk::Real bb = 1.0;
00168   mtk::Real cc = 0.0;
00169   mtk::Real dd = 1.0;
00170
00171   int nn = 5;
00172   int mm = 5;
00173
00174   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00175
```

```
00176   gg.BindVectorField(VectorFieldPComponent, VectorFieldQComponent);
00177
00178   std::cout << gg << std::endl;
00179
00180   if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_05.dat", "x", "y", "v(x,y)")) {
00181     std::cerr << "Error writing to file." << std::endl;
00182   }
00183
00184   mtk::Tools::EndUnitTestNo(5);
00185 }
00186
00187 int main () {
00188
00189   std::cout << "Testing mtk::UniStgGrid2D class." << std::endl;
00190
00191   TestDefaultConstructor();
00192   TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator();
00193   TestGetters();
00194   TestBindScalarFieldWriteToFile();
00195   TestBindVectorField();
00196 }
00197
00198 #else
00199 #include <iostream>
00200 using std::cout;
00201 using std::endl;
00202 int main () {
00203   cout << "This code HAS to be compiled with support for C++11." << endl;
00204   cout << "Exiting..." << endl;
00205 }
00206 #endif
```

# Index