

## MTK: Mimetic Methods Toolkit

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# 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.

An older version of this library is available outside of GitHub... just email me about it, and you can have it... it is ugly, yet functional and more complete.

### 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 designed and developed.

### 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](mailto:esanchez@mail.sdsu.edu) - [ejspeiro](mailto:ejspeiro@mail.sdsu.edu)
2. Jose E. Castillo, Ph.D. - [jcastillo at mail dot sdsu dot edu](mailto:jcastillo@mail.sdsu.edu)
3. Guillermo F. Miranda, Ph.D. - [unigrav at hotmail dot com](mailto:unigrav@hotmail.com)
4. Christopher P. Paolini, Ph.D. - [paolini at engineering dot sdsu dot edu](mailto:paolini@engineering.sdsu.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. 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. Compiler: gcc version 4.4.5 (Ubuntu/Linaro 4.4.4-14ubuntu5). Copyright (C) 2013 Free Software Foundation, Inc.
3. Debugger: GNU gdb (Ubuntu 7.7.1-0ubuntu5~14.04.2) 7.7.1. Copyright (C) 2014 Free Software Foundation, Inc.
4. Memory Profiler: valgrind-3.10.0.SVN.



## Chapter 3

# Licensing and Modifications

Copyright (C) 2015, Computational Science Research Center, San Diego State University. All rights reserved.

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](mailto: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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## 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.

An older version of this library is available outside of GitHub... just email me about it, and you can have it... it is ugly, yet functional and more complete.

#### 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 to 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
```

Examples and tests will also be built.

## 4. Frequently Asked Questions

Q: Why haven't you guys implemented GBS to build the library?

A: I'm on it as we speak! ;)

Q: Is there any main reference when it comes to the theory on Mimetic Methods?

A: Yes! Check: <http://www.csrc.sdsu.edu/mimetic-book>

Q: Do I need to generate the documentation myself?

A: You can if you want to... but if you DO NOT want to, just go to our website.

## 5. 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:

**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. Linux 3.2.0-23-generic-pae #36-Ubuntu SMP i386 GNU/Linux.  
Intel(R) Pentium(R) M CPU 1.73 GHz 2048 KB of cache and stepping of 8.  
gcc version 4.6.3 (Ubuntu/Linaro 4.6.3-1ubuntu5).
2. Linux 3.13.0-67-generic #110-Ubuntu SMP x86\_64 GNU/Linux.  
Intel(R) Core(TM) i7-4700MQ CPU 2.40 GHz 6144 KB of cache and stepping of 3.  
gcc version 4.8.4 (Ubuntu 4.4.4-2ubuntu1~14.04).
3. Linux 3.16.7-29-desktop #1 SMP PREEMPT (6be6a97) x86\_64 GNU/Linux  
Intel(R) Core(TM) i7-4600U CPU 2.10 GHz 4096 KB of cache and a stepping of 1.  
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 UniStgGrid2D &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 UniStgGrid2D &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.

**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.



## 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

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## Chapter 11

# Namespace Index

### 11.1 Namespace List

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## Chapter 12

# Class Index

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## Chapter 13

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## 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/Scalar_field)  
[https://en.wikipedia.org/wiki/Vector\\_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](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.*

### 14.6.1 Detailed Description

Uniform rectangular staggered grids.

## 14.7 Mimetic operators.

Mimetic operators.

### Classes

- class [mtk::Div1D](#)  
*Implements a 1D mimetic divergence operator.*
- class [mtk::Div2D](#)  
*Implements a 2D mimetic divergence operator.*
- class [mtk::Grad1D](#)  
*Implements a 1D mimetic gradient operator.*
- class [mtk::Grad2D](#)  
*Implements a 2D 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::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 [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 [GLPKAdapter](#)  
*Adapter class for the GLPK API.*
- class [Grad1D](#)  
*Implements a 1D mimetic gradient operator.*
- class [Grad2D](#)  
*Implements a 2D 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 [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.*

## 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)

## 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::UniStgGrid2D & in )`

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

Definition at line 67 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

15.1.1.3 `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](#).

15.1.1.4 `std::ostream& mtk::operator<< ( std::ostream & stream, mtk::Lap1D & in )`

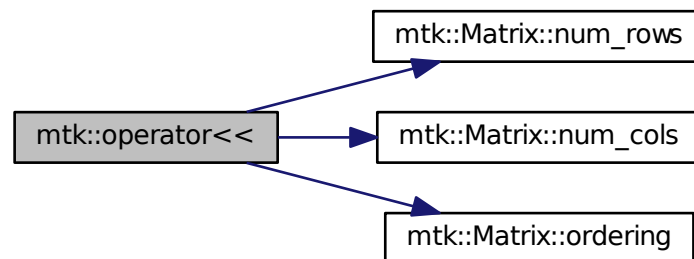
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 73 of file [mtk\\_lap\\_1d.cc](#).

15.1.1.5 `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:



15.1.1.6 `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](#).

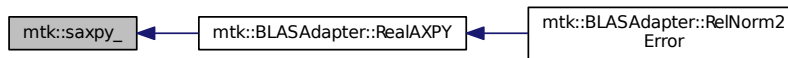
15.1.1.7 `std::ostream& mtk::operator<< ( std::ostream & stream, mtk::Div1D & in )`

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](#).

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

Here is the caller graph for this function:

15.1.1.9 `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  $m \geq n$ : find the least squares solution of an overdetermined system, i.e., solve the least squares problem

$$\text{minimize } || B - A * X ||.$$

2. If TRANS = 'N' and  $m < n$ : find the minimum norm solution of an underdetermined system  $A * X = B$ .
3. If TRANS = 'T' and  $m \geq n$ : 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

$$\text{minimize } || B - A^{**T} * X ||.$$

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.

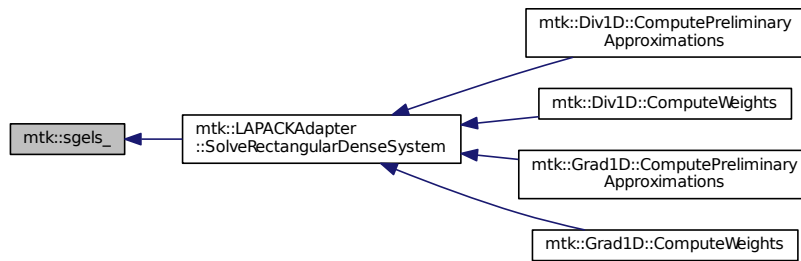
See also

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

## Parameters

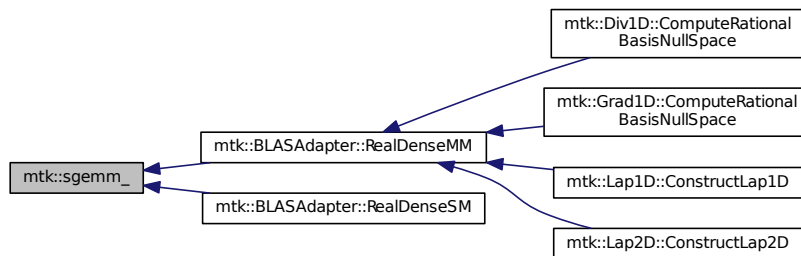
in	<i>trans</i>	Am I giving the transpose of the matrix?
in	<i>m</i>	The number of rows of the matrix a. $m \geq 0$ .
in	<i>n</i>	The number of columns of the matrix a. $n \geq 0$ .
in	<i>nrhs</i>	The number of right-hand sides.
in,out	<i>a</i>	On entry, the m-by-n matrix a.
in	<i>lda</i>	The leading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

Here is the caller graph for this function:



15.1.1.10 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:



15.1.1.11 `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:



15.1.1.12 `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

$$Q = H(1) H(2) \dots H(k)$$

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

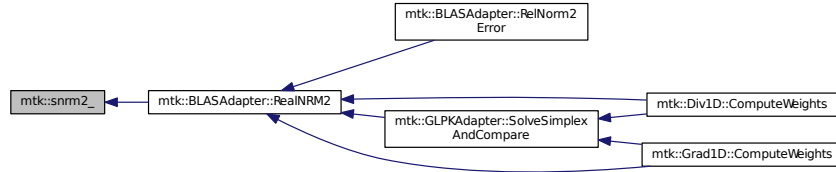
#### Parameters

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

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

#### 15.1.1.14 float mtk::snrm2\_ ( int \* *n*, float \* *x*, int \* *incx* )

Here is the caller graph for this function:



#### 15.1.1.15 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':  $Q * C * Q^T$  TRANS = 'T':  $Q^{*T} * C * Q^{*T}$

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

$$Q = H(1) H(2) \dots H(k)$$

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

#### Parameters

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



---

<code>in, out</code>	<i>info</i>	info = 0: successful exit.
----------------------	-------------	----------------------------



## Chapter 16

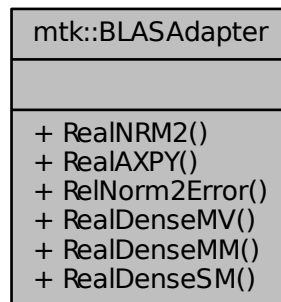
# Class Documentation

### 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  $\|x\|_2$  of given array `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

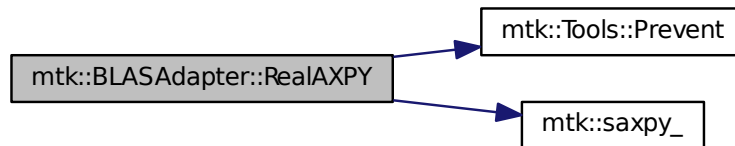
in	alpha	Scalar of the first array.
in	xx	First array.
in	yy	Second array.
in	in_length	Lengths of the given arrays.

**Returns**

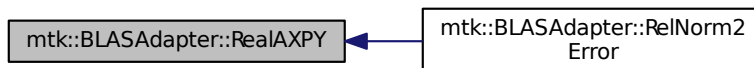
Norm-2 of the given array.

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	<i>aa</i>	First matrix.
in	<i>bb</i>	Second matrix.

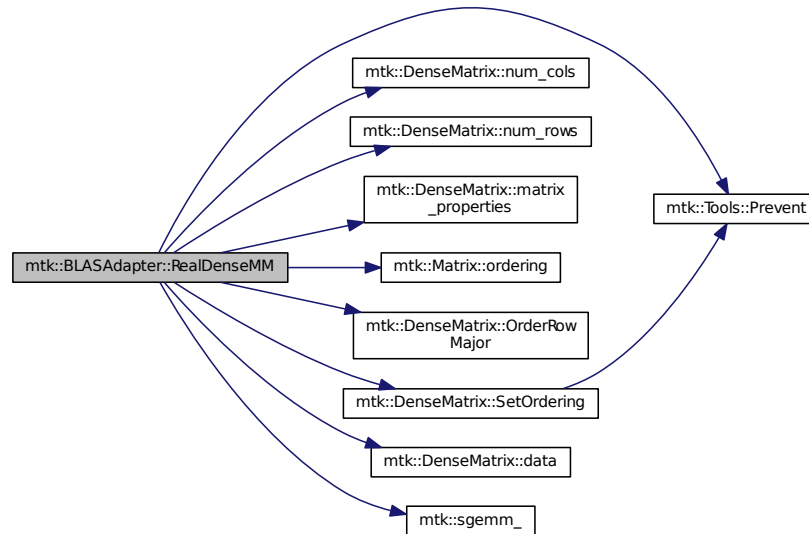
**See also**

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

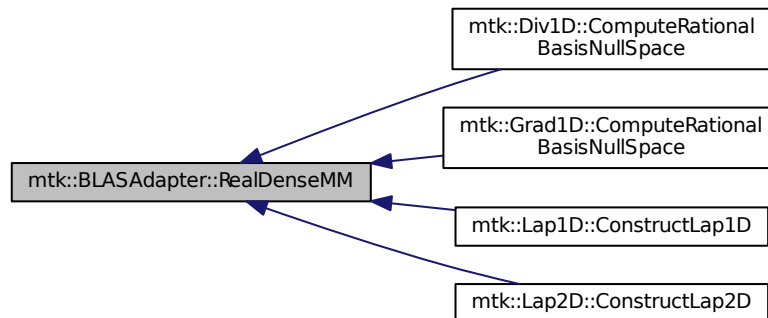
1. Make sure input matrices are row-major ordered.
2. Setup the problem.
3. Perform multiplication.

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

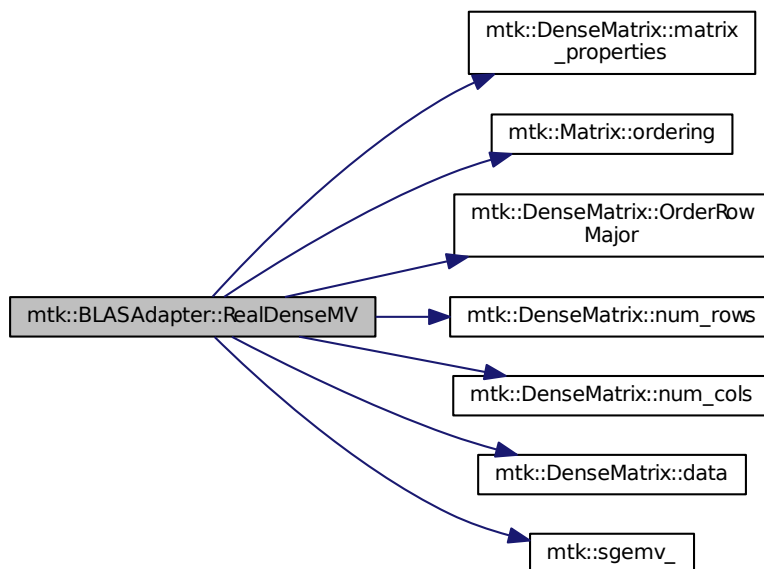
in	<i>alpha</i>	First scalar.
in	<i>aa</i>	Given matrix.
in	<i>xx</i>	First vector.
in	<i>beta</i>	Second scalar.
in, out	<i>yy</i>	Second vector (output).

## See also

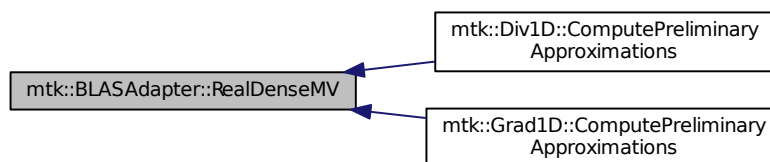
<http://ejspeiro.github.io/Netlib-and-CPP/>

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	<i>alpha</i>	Input scalar.
in	<i>aa</i>	Input matrix.

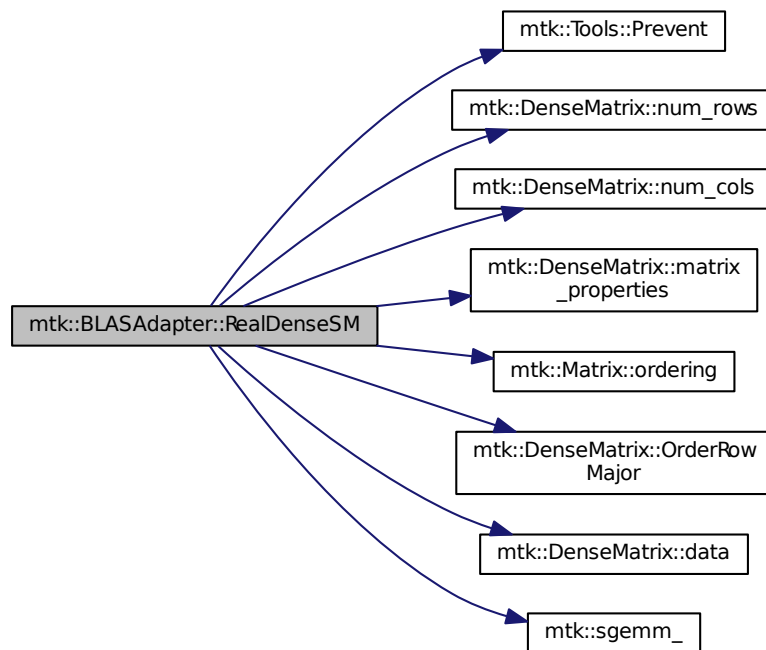
See also

<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

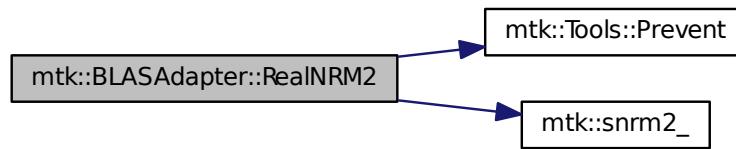
<code>in</code>	<code>in</code>	Input array.
<code>in</code>	<code>in_length</code>	Length of the array.

## Returns

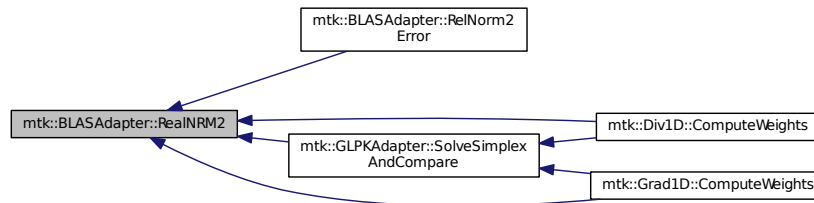
Norm-2 of the given array.

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**

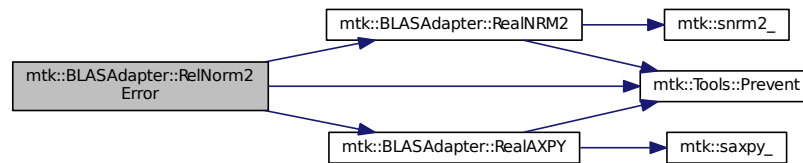
in	<i>known</i>	Array containing the computed solution.
in	<i>computed</i>	Array containing the known solution (ref. solution).

**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:

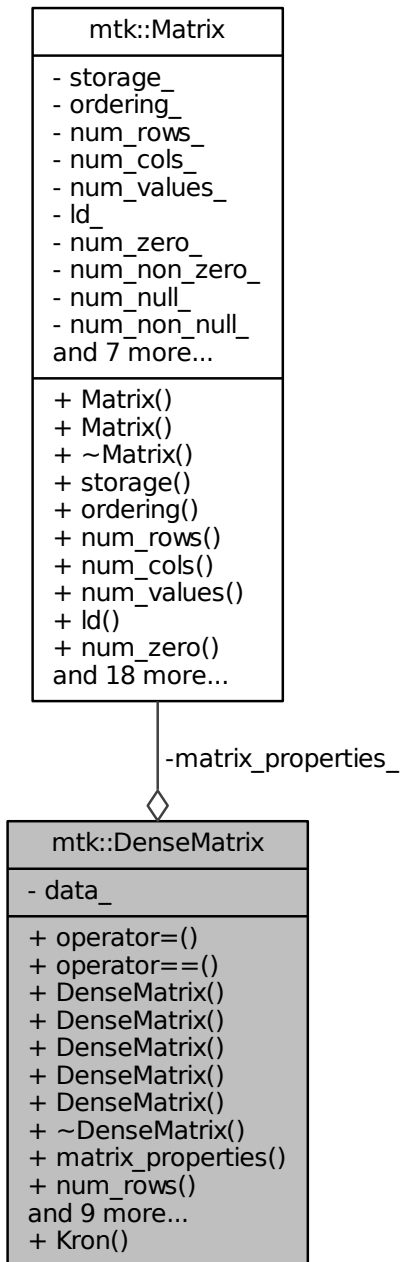
- [include/mtk\\_blas\\_adapter.h](#)
- [src/mtk\\_blas\\_adapter.cc](#)

## 16.2 mtk::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).*

### 16.2.1 Detailed Description

For developing purposes, it is better to have a not-so-intricated 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.

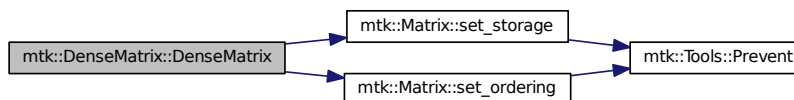
Definition at line 92 of file [mtk\\_dense\\_matrix.h](#).

### 16.2.2 Constructor & Destructor Documentation

#### 16.2.2.1 `mtk::DenseMatrix::DenseMatrix ( )`

Definition at line 162 of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:



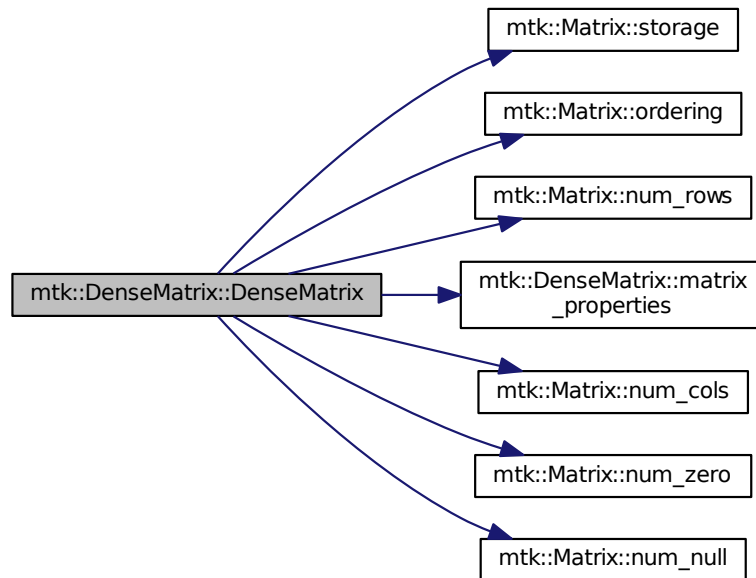
#### 16.2.2.2 `mtk::DenseMatrix::DenseMatrix ( const DenseMatrix &in )`

##### Parameters

<code>in</code>	<i>in</i>	Given matrix.
-----------------	-----------	---------------

Definition at line 168 of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:



### 16.2.2.3 `mtk::DenseMatrix::DenseMatrix ( const int & num_rows, const int & num_cols )`

#### Parameters

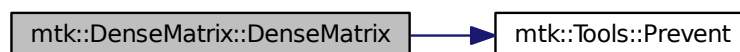
in	<i>num_rows</i>	Number of rows of the required matrix.
in	<i>num_cols</i>	Number of rows of the required matrix.

#### Exceptions

<i>std::bad_alloc</i>	
-----------------------	--

Definition at line 201 of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:



#### 16.2.2.4 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	<i>rank</i>	Rank or number of rows/cols in square matrix.
in	<i>padded</i>	Should it be padded?
in	<i>transpose</i>	Should I return the transpose of the requested matrix?

##### Exceptions

<i>std::bad_alloc</i>	
-----------------------	--

Definition at line 223 of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:



#### 16.2.2.5 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 is 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 neither the CRS nor the CBS algorithms may work for irregular geometries, such as curvilinear grids.

## Parameters

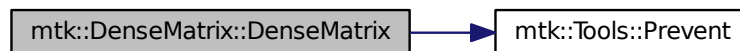
in	<i>gen</i>	Given generator vector.
in	<i>gen_length</i>	Length generator vector.
in	<i>pro_length</i>	Length the progression.
in	<i>transpose</i>	Should the transpose be created instead?

## Exceptions

<i>std::bad_alloc</i>	
-----------------------	--

Definition at line [264](#) of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:



#### 16.2.2.6 mtk::DenseMatrix::~~DenseMatrix ( )

Definition at line [312](#) of file [mtk\\_dense\\_matrix.cc](#).

### 16.2.3 Member Function Documentation

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

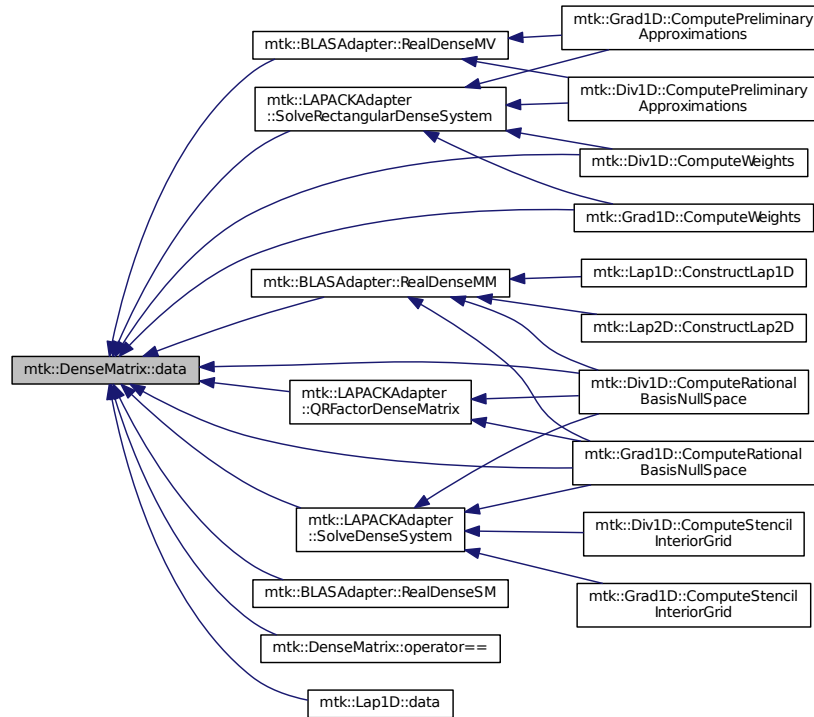


## Returns

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:



### 16.2.3.2 mtk::Real mtk::DenseMatrix::GetValue ( const int & row\_coord, const int & col\_coord ) const [noexcept]

## Parameters

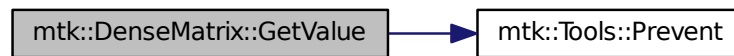
in	<i>row_coord</i>	Row coordinate.
in	<i>col_coord</i>	Column coordinate.

**Returns**

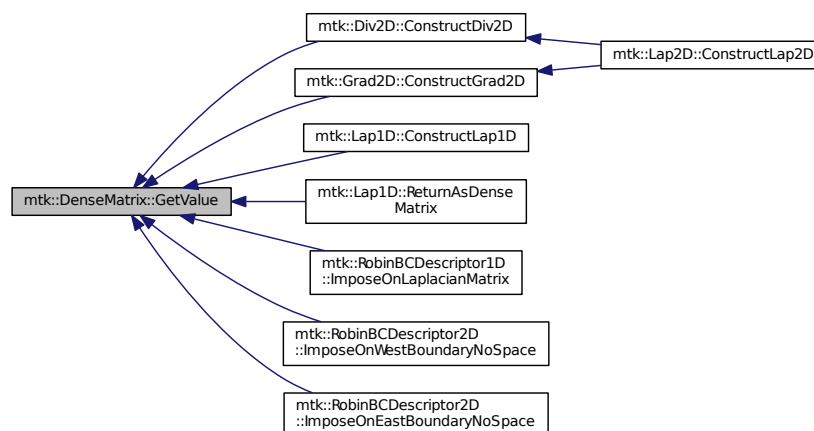
The required value at the specified coordinates.

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:



### 16.2.3.3 `mtk::DenseMatrix mtk::DenseMatrix::Kron ( const DenseMatrix & aa, const DenseMatrix & bb ) [static]`

**Parameters**

in	<i>aa</i>	First matrix.
in	<i>bb</i>	Second matrix.

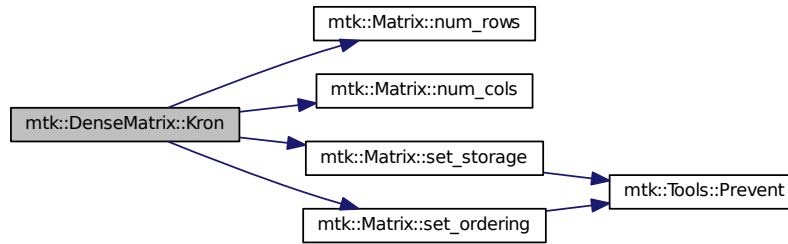
**Exceptions**

<code>std::bad_alloc</code>	
-----------------------------	--

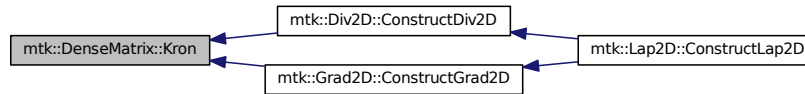
**Todo** Implement Kronecker product using the BLAS.

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:



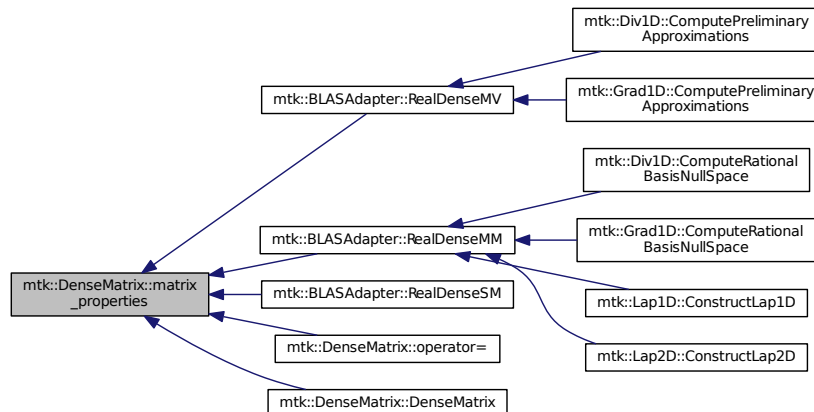
#### 16.2.3.4 mtk::Matrix mtk::DenseMatrix::matrix\_properties ( ) const [noexcept]

Returns

Pointer to a [Matrix](#).

Definition at line 318 of file [mtk\\_dense\\_matrix.cc](#).

Here is the caller graph for this function:



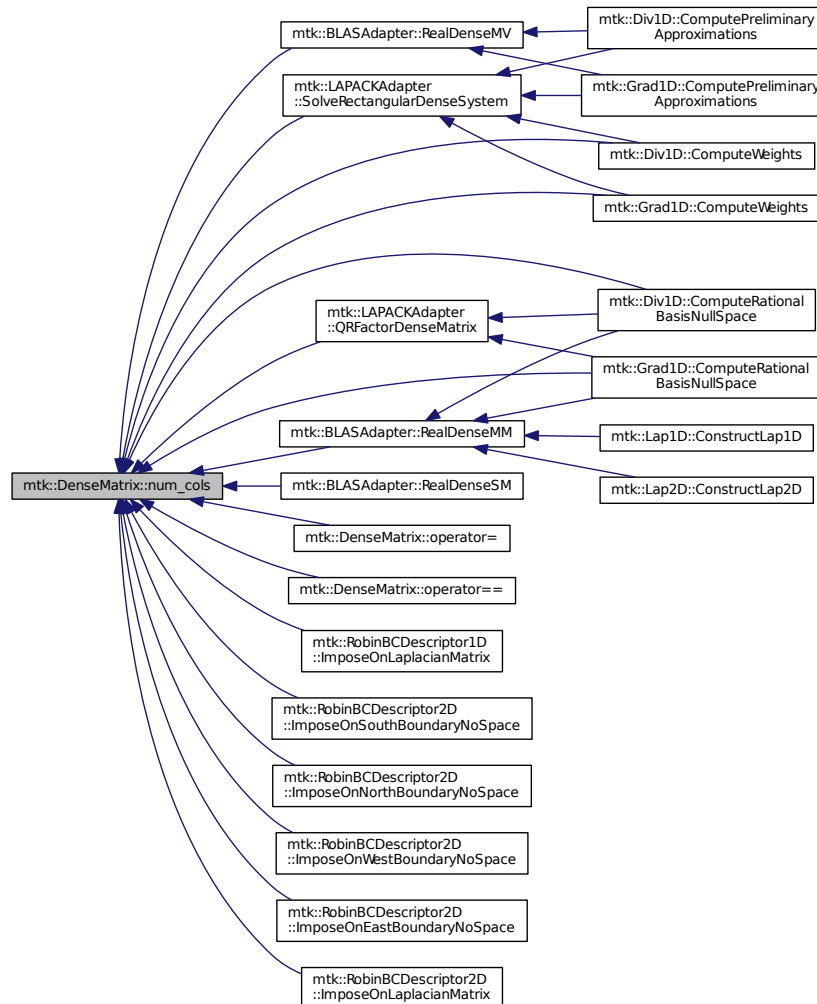
16.2.3.5 `int mtk::DenseMatrix::num_cols ( ) const [noexcept]`

#### 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:



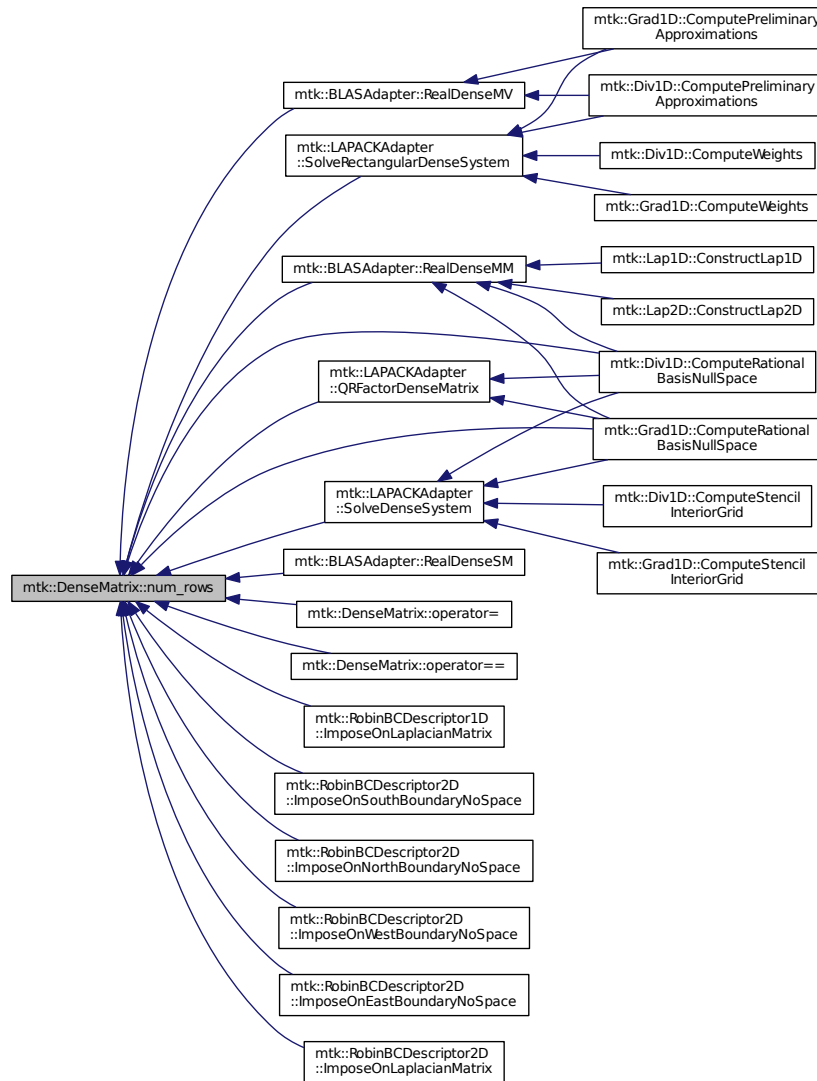
16.2.3.6 `int mtk::DenseMatrix::num_rows ( ) const [noexcept]`

## Returns

Number of rows of the matrix.

Definition at line 333 of file [mtk\\_dense\\_matrix.cc](#).

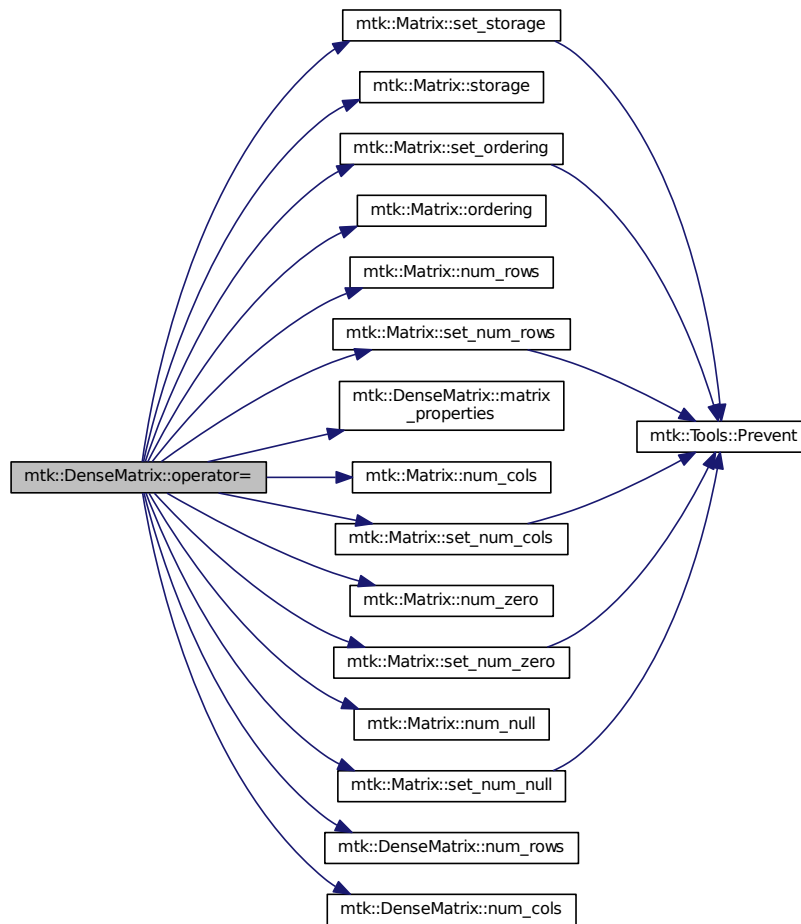
Here is the caller graph for this function:



### 16.2.3.7 mtk::DenseMatrix & mtk::DenseMatrix::operator= ( const DenseMatrix & in )

Definition at line 100 of file [mtk\\_dense\\_matrix.cc](#).

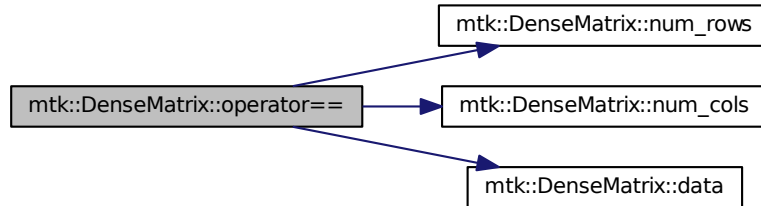
Here is the call graph for this function:



16.2.3.8 `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:

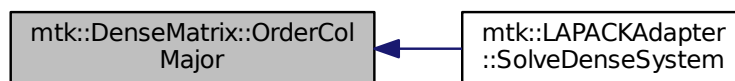


16.2.3.9 `void mtk::DenseMatrix::OrderColMajor ( )`

**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:

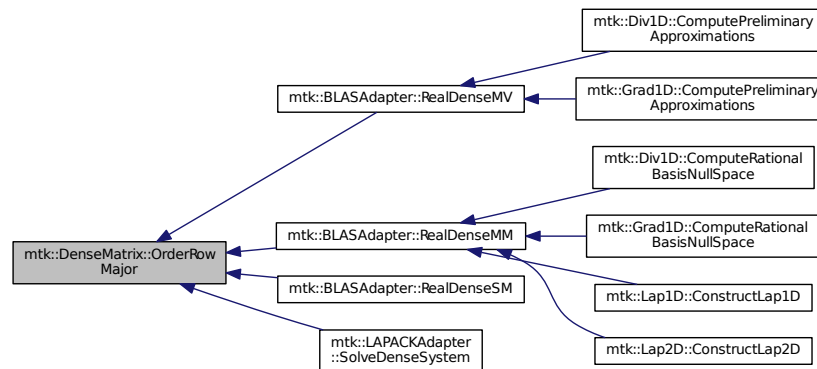


16.2.3.10 `void mtk::DenseMatrix::OrderRowMajor ( )`

**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:



**16.2.3.11** `void mtk::DenseMatrix::SetOrdering ( mtk::MatrixOrdering oo ) [noexcept]`

#### Parameters

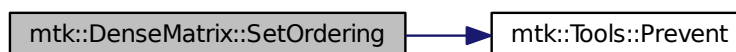
in	oo	Ordering.
----	----	-----------

#### Returns

The required value at the specified coordinates.

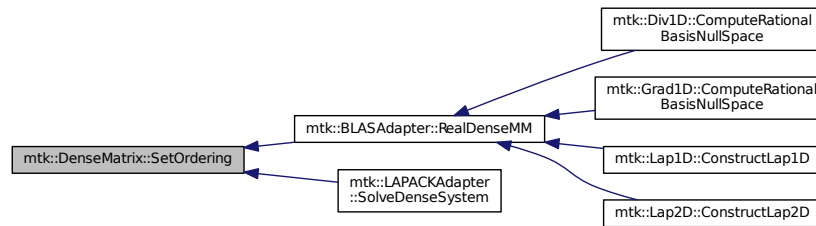
Definition at line 323 of file `mtk_dense_matrix.cc`.

Here is the call graph for this function:





Here is the caller graph for this function:



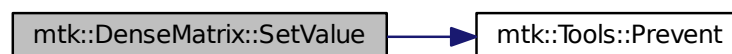
16.2.3.12 `void mtk::DenseMatrix::SetValue ( const int & row_coord, const int & col_coord, const Real & val )` [noexcept]

#### Parameters

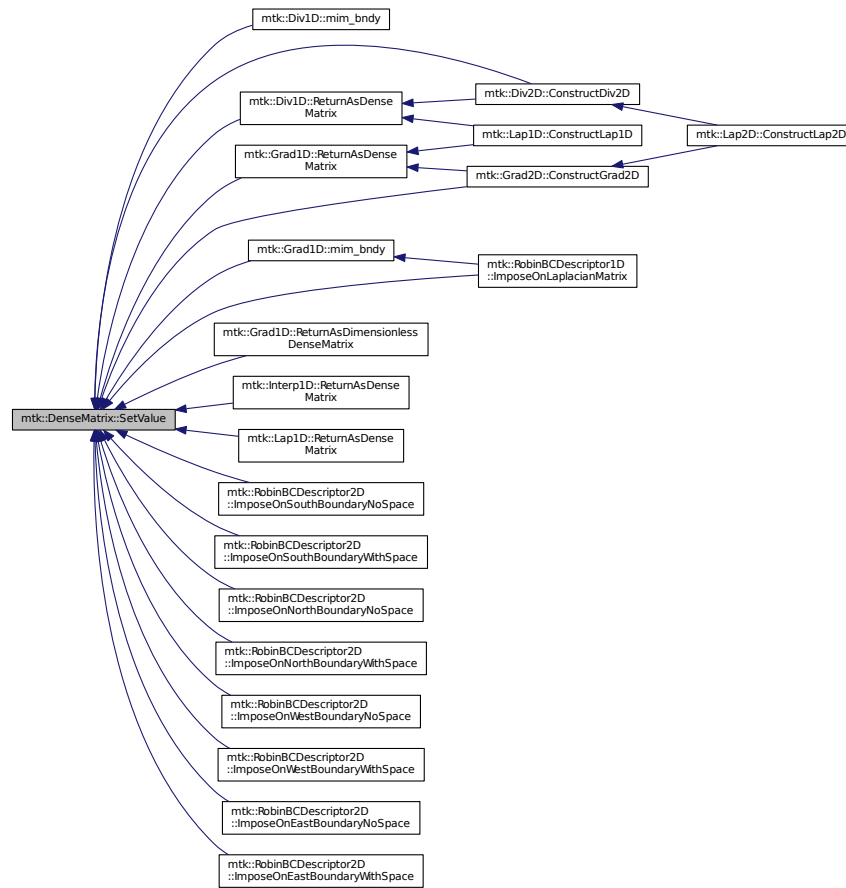
in	<i>row_coord</i>	Row coordinate.
in	<i>col_coord</i>	Column coordinate.
in	<i>val</i>	Row Actual value to be inserted.

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:

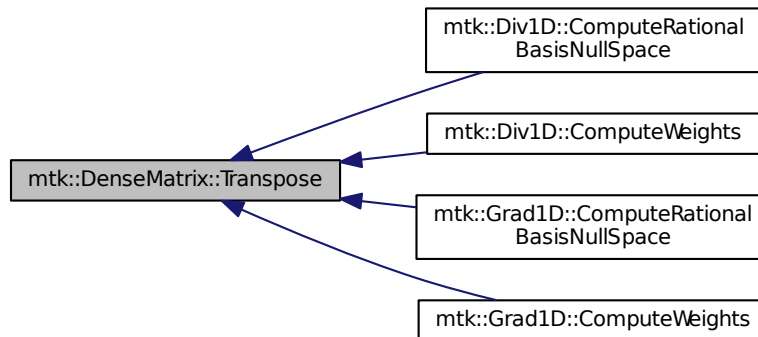


### 16.2.3.13 void mtk::DenseMatrix::Transpose ( )

**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:



16.2.3.14 `bool mtk::DenseMatrix::WriteToFile ( const std::string & filename ) const`

#### Parameters

<code>in</code>	<code>filename</code>	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`.

## 16.2.4 Friends And Related Function Documentation

16.2.4.1 `std::ostream& operator<< ( std::ostream & stream, mtk::DenseMatrix & in )` `[friend]`

Definition at line 77 of file `mtk_dense_matrix.cc`.

## 16.2.5 Member Data Documentation

16.2.5.1 `Real* mtk::DenseMatrix::data_` `[private]`

Definition at line 285 of file `mtk_dense_matrix.h`.

### 16.2.5.2 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:

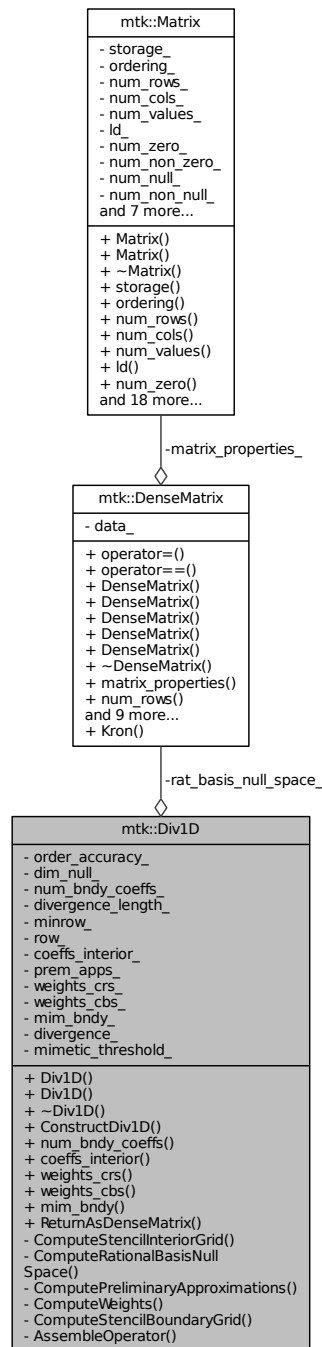
- [include/mtk\\_dense\\_matrix.h](#)
- [src/mtk\\_dense\\_matrix.cc](#)

## 16.3 `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\\_coefs](#) () const
- *Returns how many coefficients are approximating at the boundary.*
- [Real](#) \* [coefs\\_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\\_coefs\\_](#)
- *Req. coefs. 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.*

### 16.3.1 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`.

### 16.3.2 Constructor & Destructor Documentation

#### 16.3.2.1 `mtk::Div1D::Div1D ( )`

Definition at line 125 of file `mtk_div_1d.cc`.

#### 16.3.2.2 `mtk::Div1D::Div1D ( const Div1D &div )`

##### Parameters

<code>in</code>	<code>div</code>	Given divergence.
-----------------	------------------	-------------------

Definition at line 140 of file `mtk_div_1d.cc`.

#### 16.3.2.3 `mtk::Div1D::~~Div1D ( )`

Definition at line 155 of file `mtk_div_1d.cc`.

### 16.3.3 Member Function Documentation

#### 16.3.3.1 `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](#).

#### 16.3.3.2 `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](#).

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

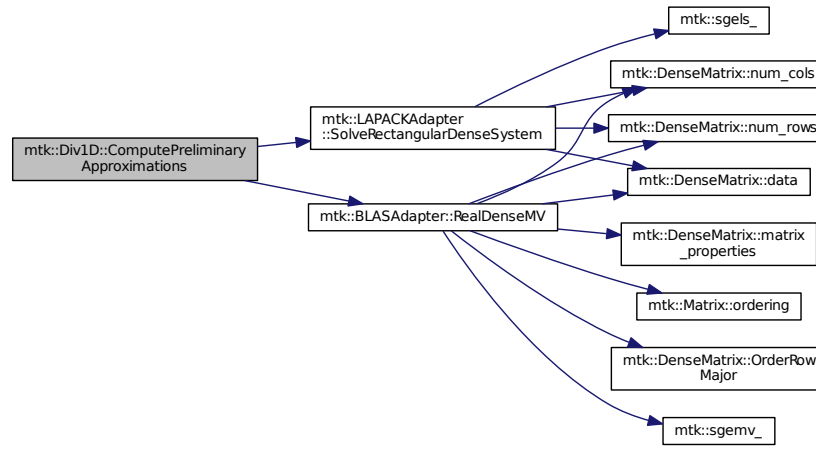
Compute the set of preliminary approximations on the boundary neighborhood.

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:



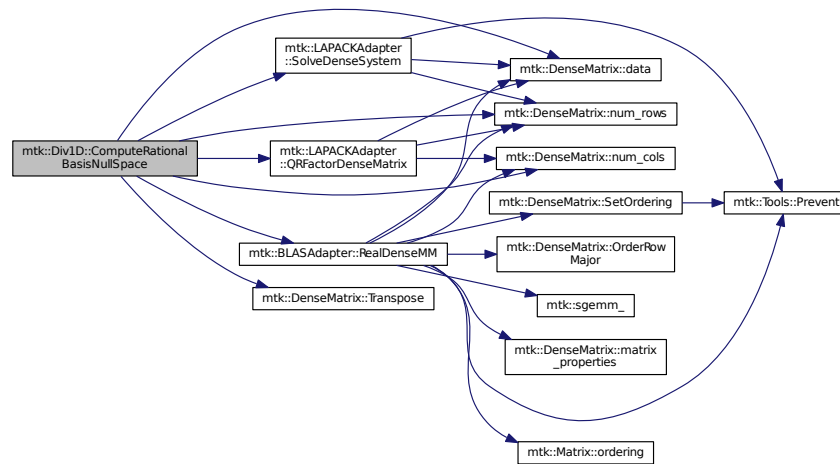
#### 16.3.3.4 `bool mtk::Div1D::ComputeRationalBasisNullSpace ( void ) [private]`

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:



#### 16.3.3.5 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](#).

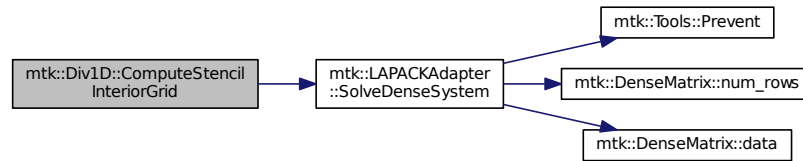
#### 16.3.3.6 bool mtk::Div1D::ComputeStencilInteriorGrid ( void ) [private]

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:



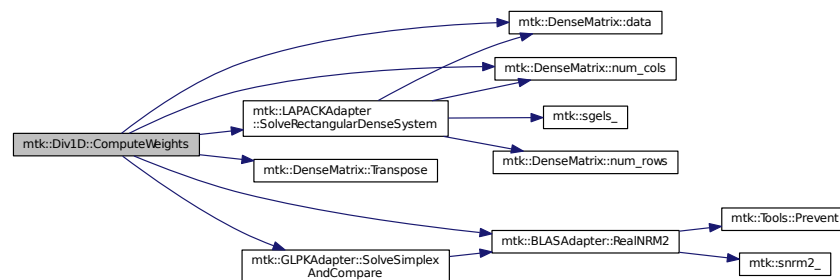
#### 16.3.3.7 bool mtk::Div1D::ComputeWeights ( void ) [private]

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

1. Construct the  $\mathbf{A}$  matrix.
2. Use interior stencil to build proper RHS vector  $\mathbf{h}$ .
3. Get weights (as **CRSA**):  $\mathbf{A}\mathbf{q} = \mathbf{h}$ .
4. If required order is greater than critical order, start the **CBSA**.
5. Create  $\mathbf{B}$  matrix from  $\mathbf{A}$ .
6. Prepare constraint vector as in the CBSA:  $\mathbf{c}$ .
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:



16.3.3.8 `bool mtk::Div1D::ConstructDiv1D ( int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### Returns

Success of the construction.

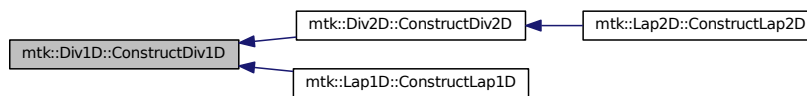
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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



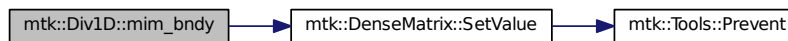
16.3.3.9 `mtk::DenseMatrix mtk::Div1D::mim_bndy ( ) const`

**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:

**16.3.3.10 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](#).

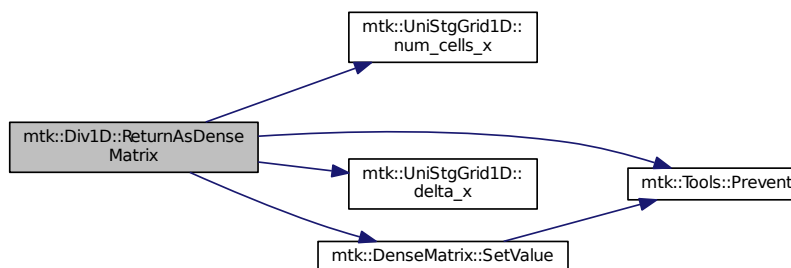
**16.3.3.11 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix ( const UniStgGrid1D & grid ) const****Returns**

The operator as a dense matrix.

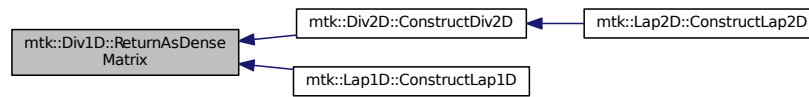
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

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:



#### 16.3.3.12 `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](#).

#### 16.3.3.13 `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](#).

### 16.3.4 Friends And Related Function Documentation

#### 16.3.4.1 `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](#).

### 16.3.5 Member Data Documentation

#### 16.3.5.1 `Real* mtk::Div1D::coeffs_interior_` [*private*]

Definition at line 202 of file [mtk\\_div\\_1d.h](#).

#### 16.3.5.2 `int mtk::Div1D::dim_null_` [*private*]

Definition at line 194 of file [mtk\\_div\\_1d.h](#).

**16.3.5.3** `Real* mtk::Div1D::divergence_` [private]

Definition at line 207 of file [mtk\\_div\\_1d.h](#).

**16.3.5.4** `int mtk::Div1D::divergence_length_` [private]

Definition at line 196 of file [mtk\\_div\\_1d.h](#).

**16.3.5.5** `Real* mtk::Div1D::mim_bndy_` [private]

Definition at line 206 of file [mtk\\_div\\_1d.h](#).

**16.3.5.6** `Real mtk::Div1D::mimetic_threshold_` [private]

Definition at line 209 of file [mtk\\_div\\_1d.h](#).

**16.3.5.7** `int mtk::Div1D::minrow_` [private]

Definition at line 197 of file [mtk\\_div\\_1d.h](#).

**16.3.5.8** `int mtk::Div1D::num_bndy_coeffs_` [private]

Definition at line 195 of file [mtk\\_div\\_1d.h](#).

**16.3.5.9** `int mtk::Div1D::order_accuracy_` [private]

Definition at line 193 of file [mtk\\_div\\_1d.h](#).

**16.3.5.10** `Real* mtk::Div1D::prem_apps_` [private]

Definition at line 203 of file [mtk\\_div\\_1d.h](#).

**16.3.5.11** `DenseMatrix mtk::Div1D::rat_basis_null_space_` [private]

Definition at line 200 of file [mtk\\_div\\_1d.h](#).

**16.3.5.12** `int mtk::Div1D::row_` [private]

Definition at line 198 of file [mtk\\_div\\_1d.h](#).

**16.3.5.13** `Real* mtk::Div1D::weights_cbs_` [private]

Definition at line 205 of file [mtk\\_div\\_1d.h](#).

16.3.5.14 `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](#)

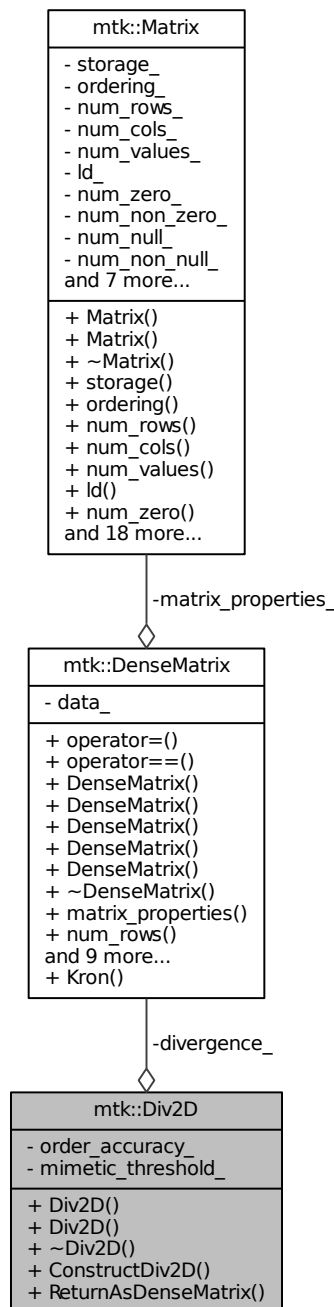
## 16.4 `mtk::Div2D` Class Reference

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.*

## 16.4.1 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](#).

## 16.4.2 Constructor & Destructor Documentation

### 16.4.2.1 [mtk::Div2D::Div2D](#) ( )

Definition at line 69 of file [mtk\\_div\\_2d.cc](#).

### 16.4.2.2 [mtk::Div2D::Div2D](#) ( const [Div2D](#) &div )

#### Parameters

<a href="#">in</a>	<a href="#">div</a>	Given divergence.
--------------------	---------------------	-------------------

Definition at line 73 of file [mtk\\_div\\_2d.cc](#).

### 16.4.2.3 [mtk::Div2D::~~Div2D](#) ( )

Definition at line 77 of file [mtk\\_div\\_2d.cc](#).

### 16.4.3 Member Function Documentation

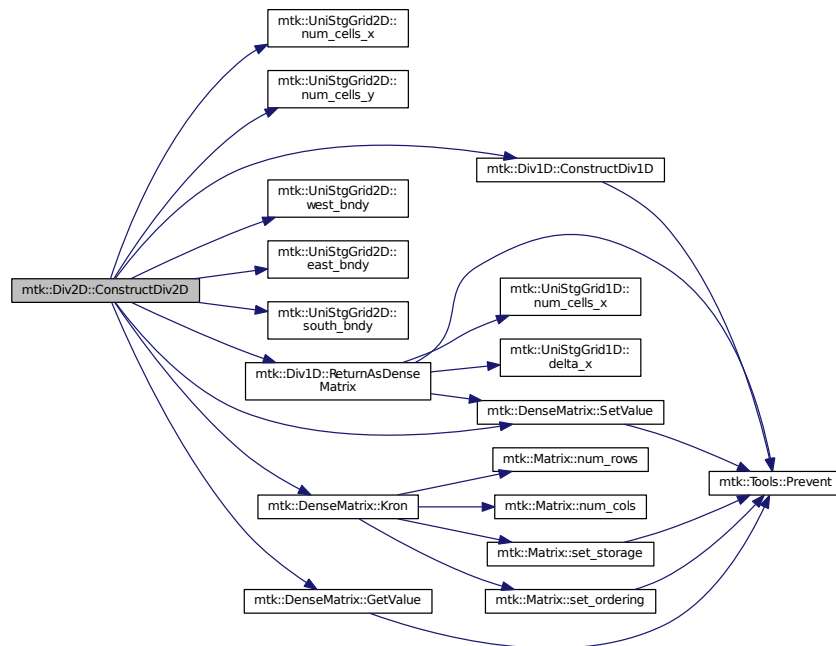
16.4.3.1 `bool mtk::Div2D::ConstructDiv2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### 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:



16.4.3.2 `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:

**16.4.4 Member Data Documentation****16.4.4.1 DenseMatrix mtk::Div2D::divergence\_ [private]**

Definition at line 108 of file [mtk\\_div\\_2d.h](#).

**16.4.4.2 Real mtk::Div2D::mimetic\_threshold\_ [private]**

Definition at line 112 of file [mtk\\_div\\_2d.h](#).

**16.4.4.3 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:

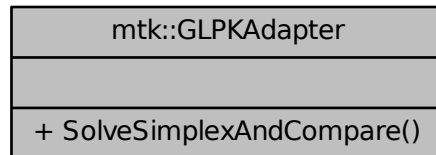
- [include/mtk\\_div\\_2d.h](#)
- [src/mtk\\_div\\_2d.cc](#)

**16.5 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.*

#### 16.5.1 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`.

### 16.5.2 Member Function Documentation

**16.5.2.1** `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	<i>alpha</i>	First scalar.
in	<i>AA</i>	Given matrix.
in	<i>xx</i>	First vector.
in	<i>beta</i>	Second scalar.
in	<i>beta</i>	Second scalar.
in, out	<i>yy</i>	Second vector (output).
in	<i>xx</i>	First vector.
in	<i>beta</i>	Second scalar.
in	<i>beta</i>	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.

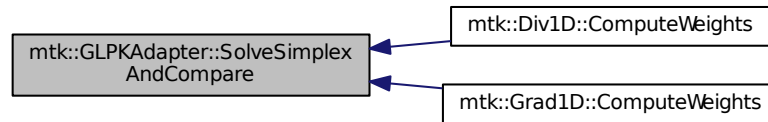
1. Memory allocation.
2. Fill the problem.
3. Copy the row to the vector objective.
4. Forming the RHS.
5. Setting up the objective function.
6. Setting up constraints.
7. Copy the matrix minus the row objective to the glpk problem.
8. Solve problem.

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:

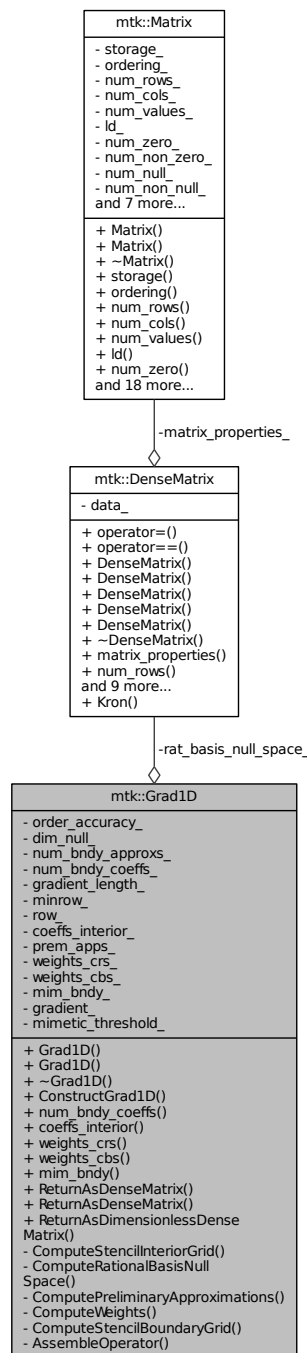
- [include/mtk\\_glpk\\_adapter.h](#)
- [src/mtk\\_glpk\\_adapter.cc](#)

## 16.6 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=[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
- 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.*

### 16.6.1 Detailed Description

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

Definition at line 81 of file [mtk\\_grad\\_1d.h](#).

### 16.6.2 Constructor & Destructor Documentation

#### 16.6.2.1 [mtk::Grad1D::Grad1D](#) ( )

Definition at line 129 of file [mtk\\_grad\\_1d.cc](#).

#### 16.6.2.2 [mtk::Grad1D::Grad1D](#) ( const [Grad1D](#) &grad )

## Parameters

<i>in</i>	<i>div</i>	Given divergence.
-----------	------------	-------------------

Definition at line 145 of file [mtk\\_grad\\_1d.cc](#).

## 16.6.2.3 mtk::Grad1D::~~Grad1D ( )

Definition at line 161 of file [mtk\\_grad\\_1d.cc](#).

## 16.6.3 Member Function Documentation

## 16.6.3.1 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  $\text{dim\_null} + 1$  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](#).

## 16.6.3.2 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](#).

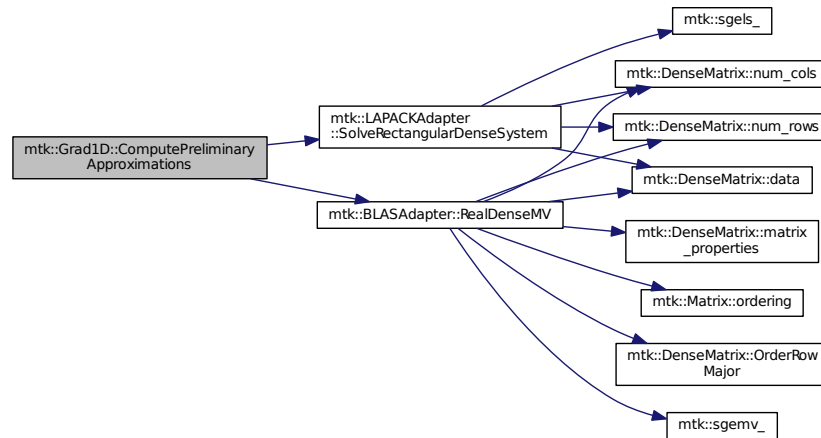
## 16.6.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations ( void ) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the  $\text{dim\_null}$  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  $\text{TT} * \text{rr} = \text{ob}$  yields the columns  $\text{rr}$  of the  $\text{kk}$  matrix.
6. Scale the  $\text{kk}$  matrix to make it a rational basis for null-space.
7. Extract the last  $\text{dim\_null}$  values of the pre-scaled  $\text{ob}$ .
8. Once we possess 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:



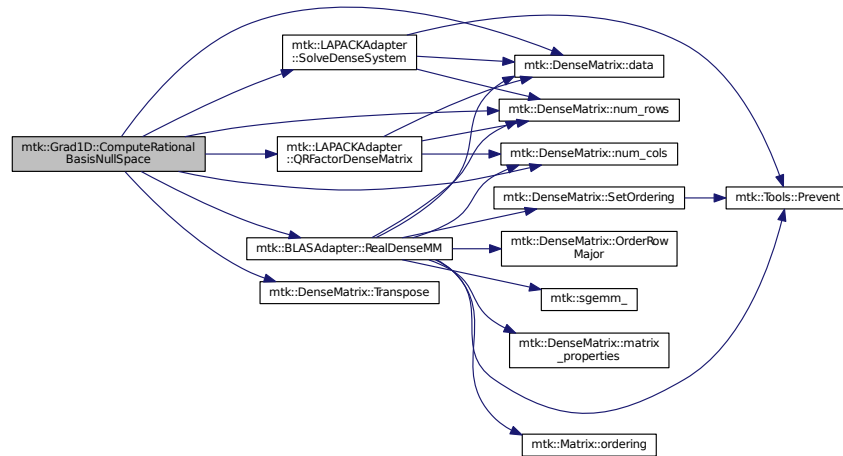
#### 16.6.3.4 `bool mtk::Grad1D::ComputeRationalBasisNullSpace( void ) [private]`

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:



#### 16.6.3.5 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](#).

#### 16.6.3.6 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:



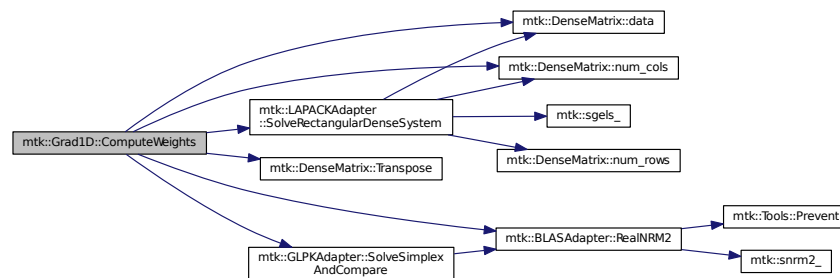
#### 16.6.3.7 bool mtk::Grad1D::ComputeWeights ( void ) [private]

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

1. Construct the  $\mathbf{M}$  matrix.
2. Use interior stencil to build proper RHS vector  $\mathbf{h}$ .
3. Get weights (as **CRSA**):  $\mathbf{M}\mathbf{q} = \mathbf{h}$ .
4. If required order is greater than critical order, start the **CBSA**.
5. Create  $\mathbf{M}$  matrix from  $\mathbf{M}$ .
6. Prepare constraint vector as in the CBSA:  $\mathbf{M}$ .
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:



#### 16.6.3.8 bool mtk::Grad1D::ConstructGrad1D ( int order\_accuracy = kDefaultOrderAccuracy, Real mimetic\_threshold = kDefaultMimeticThreshold )

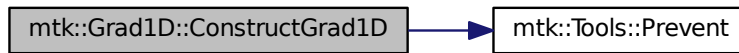
## Returns

Success of the solution.

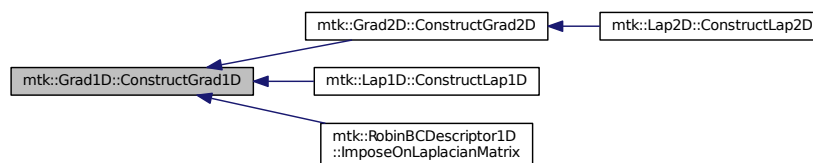
1. Compute stencil for the interior cells.
2. Compute a rational null-space from the first matrix transposed.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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



### 16.6.3.9 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:



16.6.3.10 `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](#).

16.6.3.11 `mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix ( mtk::Real west, mtk::Real east, int num_cells_x ) const`

**Returns**

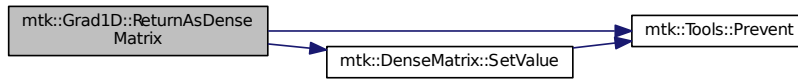
The operator as a dense matrix.

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.

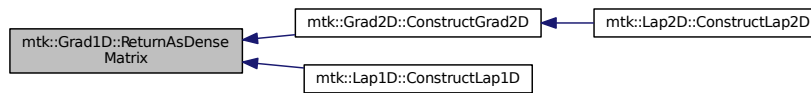
Definition at line 356 of file [mtk\\_grad\\_1d.cc](#).



Here is the call graph for this function:



Here is the caller graph for this function:



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

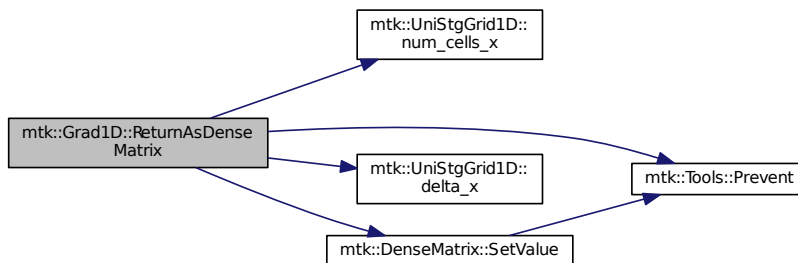
##### Returns

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:



### 16.6.3.13 `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:



### 16.6.3.14 `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](#).

### 16.6.3.15 `mtk::Real * mtk::Grad1D::weights_crs ( void ) const`

#### Returns

Success of the solution.

Definition at line 331 of file [mtk\\_grad\\_1d.cc](#).

## 16.6.4 Friends And Related Function Documentation

### 16.6.4.1 `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](#).

### 16.6.5 Member Data Documentation

#### 16.6.5.1 `Real* mtk::Grad1D::coeffs_interior_` [private]

Definition at line 217 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.2 `int mtk::Grad1D::dim_null_` [private]

Definition at line 208 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.3 `Real* mtk::Grad1D::gradient_` [private]

Definition at line 222 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.4 `int mtk::Grad1D::gradient_length_` [private]

Definition at line 211 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.5 `Real* mtk::Grad1D::mim_bndy_` [private]

Definition at line 221 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.6 `Real mtk::Grad1D::mimetic_threshold_` [private]

Definition at line 224 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.7 `int mtk::Grad1D::minrow_` [private]

Definition at line 212 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.8 `int mtk::Grad1D::num_bndy_approxs_` [private]

Definition at line 209 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.9 `int mtk::Grad1D::num_bndy_coeffs_` [private]

Definition at line 210 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.10 `int mtk::Grad1D::order_accuracy_` [private]

Definition at line 207 of file [mtk\\_grad\\_1d.h](#).

#### 16.6.5.11 `Real* mtk::Grad1D::prem_apps_` [private]

Definition at line 218 of file [mtk\\_grad\\_1d.h](#).

**16.6.5.12** `DenseMatrix mtk::Grad1D::rat_basis_null_space_` `[private]`

Definition at line 215 of file [mtk\\_grad\\_1d.h](#).

**16.6.5.13** `int mtk::Grad1D::row_` `[private]`

Definition at line 213 of file [mtk\\_grad\\_1d.h](#).

**16.6.5.14** `Real* mtk::Grad1D::weights_cbs_` `[private]`

Definition at line 220 of file [mtk\\_grad\\_1d.h](#).

**16.6.5.15** `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:

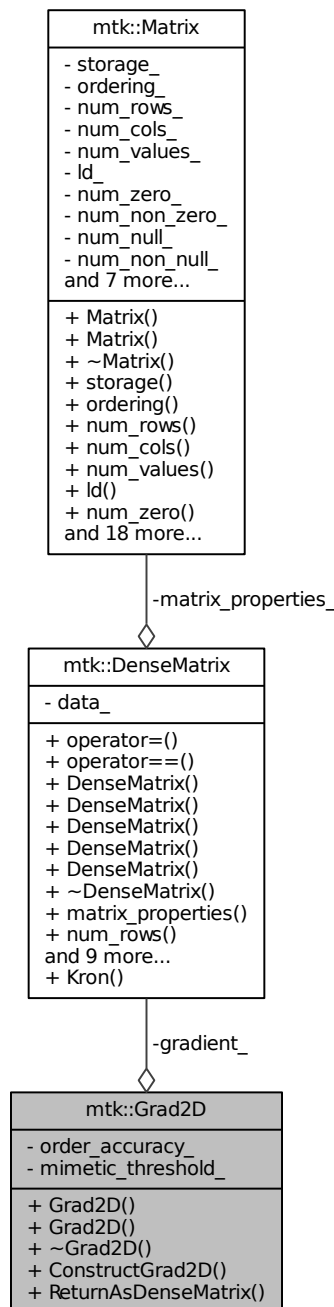
- [include/mtk\\_grad\\_1d.h](#)
- [src/mtk\\_grad\\_1d.cc](#)

## 16.7 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\_ $\leftrightarrow$  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.*

## 16.7.1 Detailed Description

This class implements a 2D gradient operator, constructed using the Castillo-Blomgren-Sanchez (CBS) Algorithm (C $\leftrightarrow$ BSA).

Definition at line 76 of file [mtk\\_grad\\_2d.h](#).

## 16.7.2 Constructor & Destructor Documentation

### 16.7.2.1 [mtk::Grad2D::Grad2D](#) ( )

Definition at line 67 of file [mtk\\_grad\\_2d.cc](#).

### 16.7.2.2 [mtk::Grad2D::Grad2D](#) ( const [Grad2D](#) &grad )

#### Parameters

<a href="#">in</a>	<a href="#">div</a>	Given divergence.
--------------------	---------------------	-------------------

Definition at line 71 of file [mtk\\_grad\\_2d.cc](#).

### 16.7.2.3 [mtk::Grad2D::~~Grad2D](#) ( )

Definition at line 75 of file [mtk\\_grad\\_2d.cc](#).

### 16.7.3 Member Function Documentation

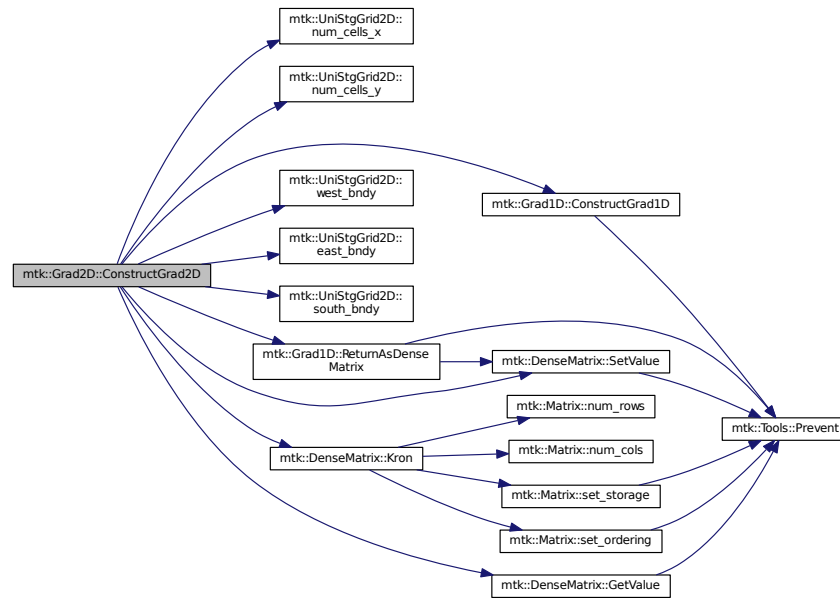
16.7.3.1 `bool mtk::Grad2D::ConstructGrad2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### 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:



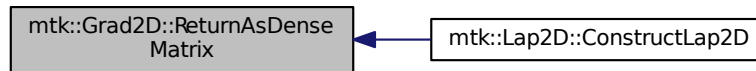
16.7.3.2 `mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix ( ) const`

**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:

**16.7.4 Member Data Documentation****16.7.4.1 DenseMatrix mtk::Grad2D::gradient\_ [private]**

Definition at line 108 of file [mtk\\_grad\\_2d.h](#).

**16.7.4.2 Real mtk::Grad2D::mimetic\_threshold\_ [private]**

Definition at line 112 of file [mtk\\_grad\\_2d.h](#).

**16.7.4.3 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](#)

**16.8 mtk::Interp1D Class Reference**

Implements a 1D interpolation operator.

```
#include <mtk_interp_1d.h>
```



Collaboration diagram for mtk::Interp1D:

mtk::Interp1D
<ul style="list-style-type: none"> <li>- dir_interp_</li> <li>- order_accuracy_</li> <li>- coeffs_interior_</li> </ul>
<ul style="list-style-type: none"> <li>+ Interp1D()</li> <li>+ Interp1D()</li> <li>+ ~Interp1D()</li> <li>+ ConstructInterp1D()</li> <li>+ coeffs_interior()</li> <li>+ ReturnAsDenseMatrix()</li> </ul>

## 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.*

### 16.8.1 Detailed Description

This class implements a 1D interpolation operator.

Definition at line 82 of file [mtk\\_interp\\_1d.h](#).

### 16.8.2 Constructor & Destructor Documentation

#### 16.8.2.1 `mtk::Interp1D::Interp1D ( )`

Definition at line 80 of file [mtk\\_interp\\_1d.cc](#).

#### 16.8.2.2 `mtk::Interp1D::Interp1D ( const Interp1D & interp )`

Parameters

<i>in</i>	<i>interp</i>	Given interpolation operator.
-----------	---------------	-------------------------------

Definition at line 85 of file [mtk\\_interp\\_1d.cc](#).

#### 16.8.2.3 `mtk::Interp1D::~~Interp1D ( )`

Definition at line 90 of file [mtk\\_interp\\_1d.cc](#).

### 16.8.3 Member Function Documentation

#### 16.8.3.1 `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](#).

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

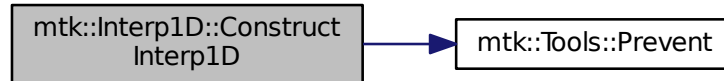
**Returns**

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:



### 16.8.3.3 `mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix ( const UniStgGrid1D & grid ) const`

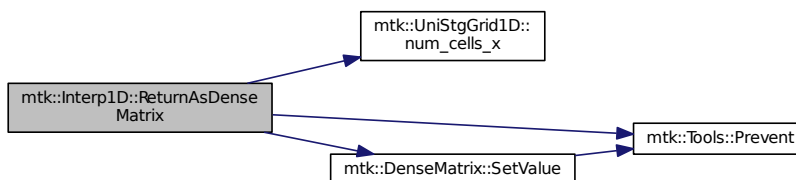
**Returns**

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:



## 16.8.4 Friends And Related Function Documentation

### 16.8.4.1 `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](#).

## 16.8.5 Member Data Documentation

### 16.8.5.1 `Real* mtk::Interp1D::coeffs_interior_` [private]

Definition at line 127 of file [mtk\\_interp\\_1d.h](#).

### 16.8.5.2 `DirInterp mtk::Interp1D::dir_interp_` [private]

Definition at line 123 of file [mtk\\_interp\\_1d.h](#).

### 16.8.5.3 `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:

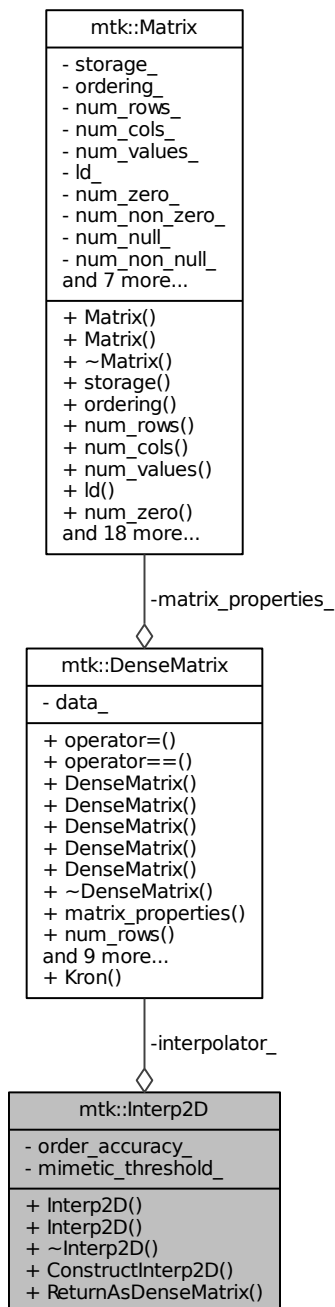
- [include/mtk\\_interp\\_1d.h](#)
- [src/mtk\\_interp\\_1d.cc](#)

## 16.9 `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.*

## 16.9.1 Detailed Description

This class implements a 2D interpolation operator.

Definition at line 76 of file [mtk\\_interp\\_2d.h](#).

## 16.9.2 Constructor & Destructor Documentation

16.9.2.1 [mtk::Interp2D::Interp2D](#) ( )

16.9.2.2 [mtk::Interp2D::Interp2D](#) ( const [Interp2D](#) & *interp* )

Parameters

<a href="#">in</a>	<a href="#">lap</a>	Given Laplacian.
--------------------	---------------------	------------------

16.9.2.3 [mtk::Interp2D::~~Interp2D](#) ( )

## 16.9.3 Member Function Documentation

16.9.3.1 [DenseMatrix mtk::Interp2D::ConstructInterp2D](#) ( const [UniStgGrid2D](#) & *grid*, int *order\_accuracy* = [kDefaultOrderAccuracy](#), [Real](#) *mimetic\_threshold* = [kDefaultMimeticThreshold](#) )

Returns

Success of the construction.

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

#### Returns

The operator as a dense matrix.

## 16.9.4 Member Data Documentation

### 16.9.4.1 DenseMatrix mtk::Interp2D::interpolator\_ [private]

Definition at line 108 of file [mtk\\_interp\\_2d.h](#).

### 16.9.4.2 Real mtk::Interp2D::mimetic\_threshold\_ [private]

Definition at line 112 of file [mtk\\_interp\\_2d.h](#).

### 16.9.4.3 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:

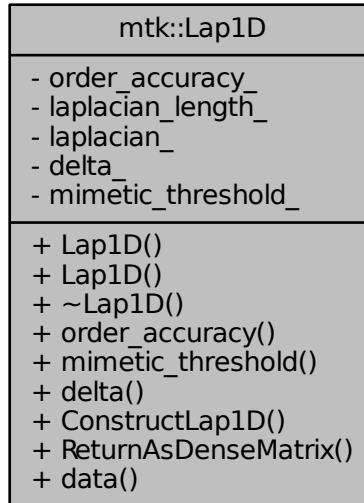
- [include/mtk\\_interp\\_2d.h](#)

## 16.10 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](#)=kDefaultMimeticThreshold)  
*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.*

### 16.10.1 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](#).

### 16.10.2 Constructor & Destructor Documentation

#### 16.10.2.1 mtk::Lap1D::Lap1D ( )

Definition at line 108 of file [mtk\\_lap\\_1d.cc](#).

#### 16.10.2.2 mtk::Lap1D::Lap1D ( const Lap1D & lap )

##### Parameters

<a href="#">in</a>	<a href="#">lap</a>	Given Laplacian.
--------------------	---------------------	------------------

#### 16.10.2.3 mtk::Lap1D::~~Lap1D ( )

Definition at line 114 of file [mtk\\_lap\\_1d.cc](#).

### 16.10.3 Member Function Documentation

#### 16.10.3.1 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.

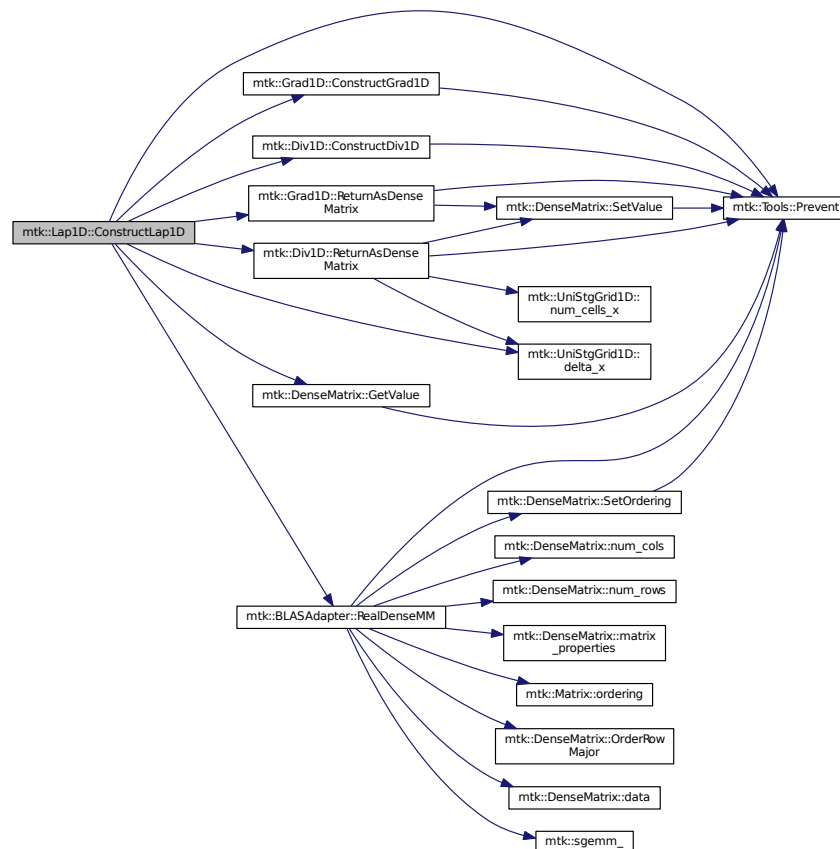
## Warning

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:



16.10.3.2 `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:



16.10.3.3 `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:



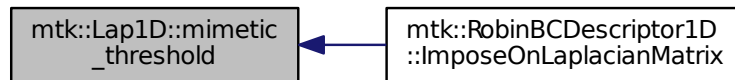
16.10.3.4 `mtk::Real mtk::Lap1D::mimetic_threshold ( ) const`

**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:



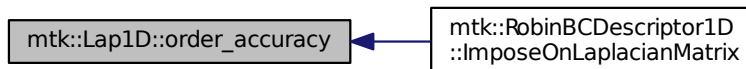
### 16.10.3.5 `int mtk::Lap1D::order_accuracy ( ) const`

**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:



### 16.10.3.6 `mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix ( const UniStgGrid1D & grid ) const`

**Returns**

The operator as a dense matrix.

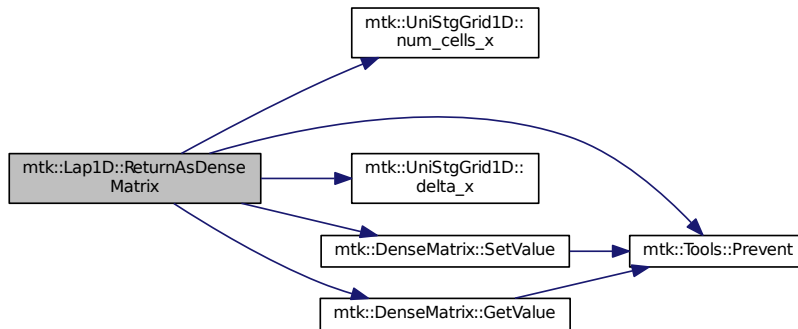
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

## 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:



### 16.10.4 Friends And Related Function Documentation

16.10.4.1 `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](#).

### 16.10.5 Member Data Documentation

16.10.5.1 `Real mtk::Lap1D::delta_` [[mutable](#)], [[private](#)]

Definition at line 143 of file [mtk\\_lap\\_1d.h](#).

16.10.5.2 `Real* mtk::Lap1D::laplacian_` [[private](#)]

Definition at line 141 of file [mtk\\_lap\\_1d.h](#).

16.10.5.3 `int mtk::Lap1D::laplacian_length_` [[private](#)]

Definition at line 139 of file [mtk\\_lap\\_1d.h](#).

#### 16.10.5.4 Real mtk::Lap1D::mimetic\_threshold\_ [private]

Definition at line 145 of file [mtk\\_lap\\_1d.h](#).

#### 16.10.5.5 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:

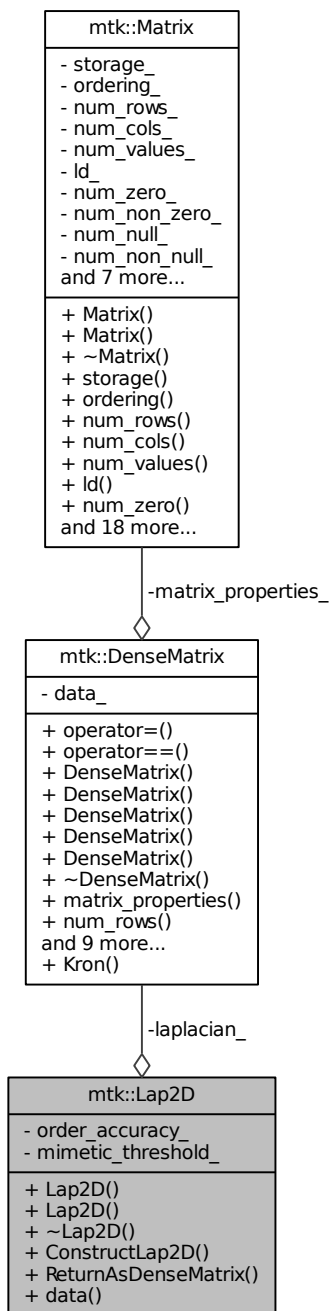
- [include/mtk\\_lap\\_1d.h](#)
- [src/mtk\\_lap\\_1d.cc](#)

## 16.11 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.*

### 16.11.1 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](#).

### 16.11.2 Constructor & Destructor Documentation

#### 16.11.2.1 [mtk::Lap2D::Lap2D \( \)](#)

Definition at line 69 of file [mtk\\_lap\\_2d.cc](#).

#### 16.11.2.2 [mtk::Lap2D::Lap2D \( const \[Lap2D\]\(#\) & lap \)](#)

##### Parameters

<a href="#">in</a>	<a href="#">lap</a>	Given Laplacian.
--------------------	---------------------	------------------

Definition at line 71 of file [mtk\\_lap\\_2d.cc](#).

#### 16.11.2.3 [mtk::Lap2D::~~Lap2D \( \)](#)

Definition at line 75 of file [mtk\\_lap\\_2d.cc](#).



### 16.11.3 Member Function Documentation

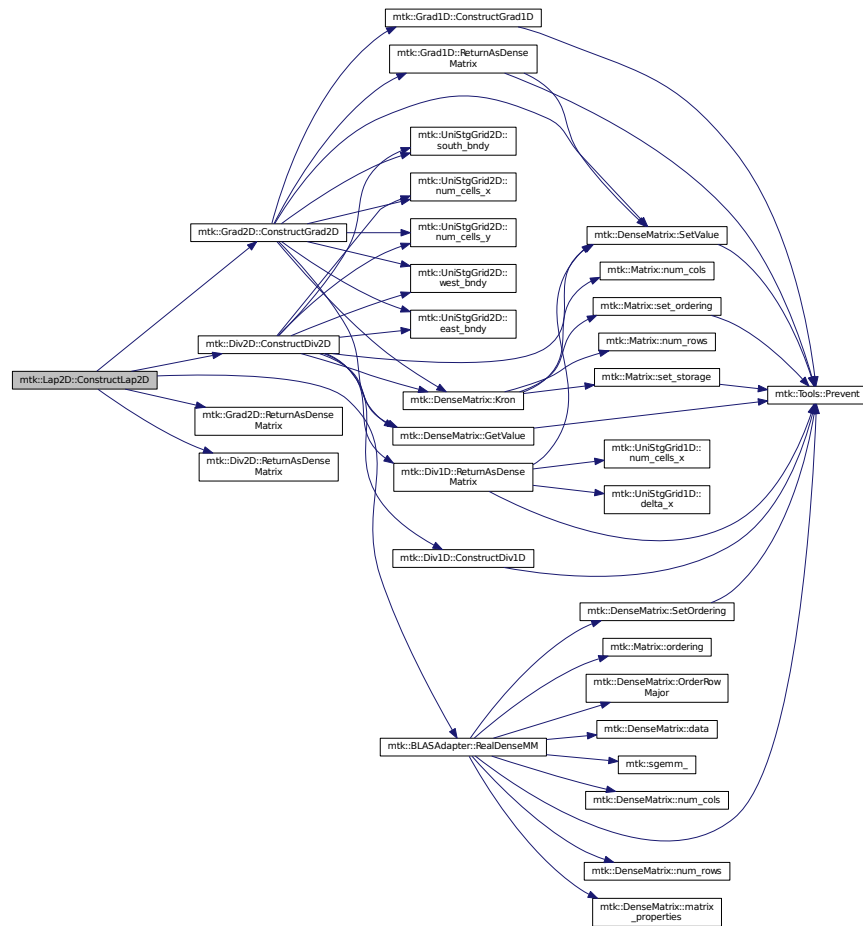
16.11.3.1 `bool mtk::Lap2D::ConstructLap2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### Returns

Success of the construction.

Definition at line 77 of file [mtk\\_lap\\_2d.cc](#).

Here is the call graph for this function:



16.11.3.2 `mtk::Real * mtk::Lap2D::data ( ) const`

#### Returns

The operator as a dense array.

Definition at line 115 of file [mtk\\_lap\\_2d.cc](#).

### 16.11.3.3 `mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix ( ) const`

#### Returns

The operator as a dense matrix.

Definition at line 110 of file [mtk\\_lap\\_2d.cc](#).

## 16.11.4 Member Data Documentation

### 16.11.4.1 `DenseMatrix mtk::Lap2D::laplacian_ [private]`

Definition at line 115 of file [mtk\\_lap\\_2d.h](#).

### 16.11.4.2 `Real mtk::Lap2D::mimetic_threshold_ [private]`

Definition at line 119 of file [mtk\\_lap\\_2d.h](#).

### 16.11.4.3 `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:

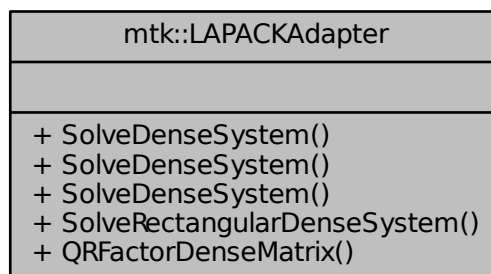
- [include/mtk\\_lap\\_2d.h](#)
- [src/mtk\\_lap\\_2d.cc](#)

## 16.12 `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 [SolveRectangularDenseSystem](#) (const mtk::DenseMatrix &aa, mtk::Real \*ob\_, int ob\_Id\_)  
*Solves overdetermined or underdetermined real linear systems.*
- static mtk::DenseMatrix [QRFactorDenseMatrix](#) (DenseMatrix &matrix)  
*Performs a QR factorization on a dense matrix.*

### 16.12.1 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 92 of file [mtk\\_lapack\\_adapter.h](#).

### 16.12.2 Member Function Documentation

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

Adapts the MTK to LAPACK's routine.

Parameters

<i>in, out</i>	<i>matrix</i>	Input matrix.
----------------	---------------	---------------

Returns

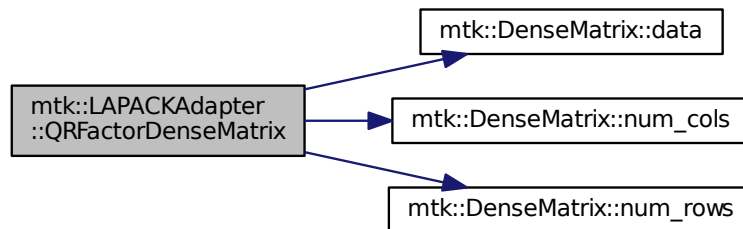
[Matrix Q](#).

Exceptions

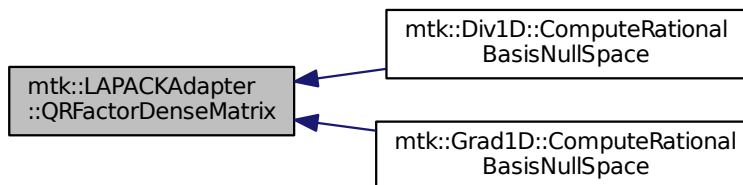
<i>std::bad_alloc</i>
-----------------------

Definition at line 555 of file [mtk\\_lapack\\_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Adapts the MTK to LAPACK's `dgesv_` routine.

#### Parameters

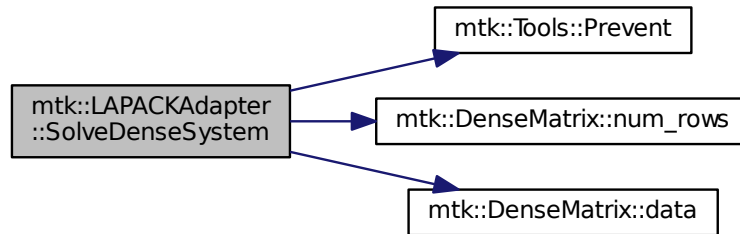
<code>in</code>	<code>matrix</code>	Input matrix.
<code>in</code>	<code>rhs</code>	Input right-hand sides vector.

#### Exceptions

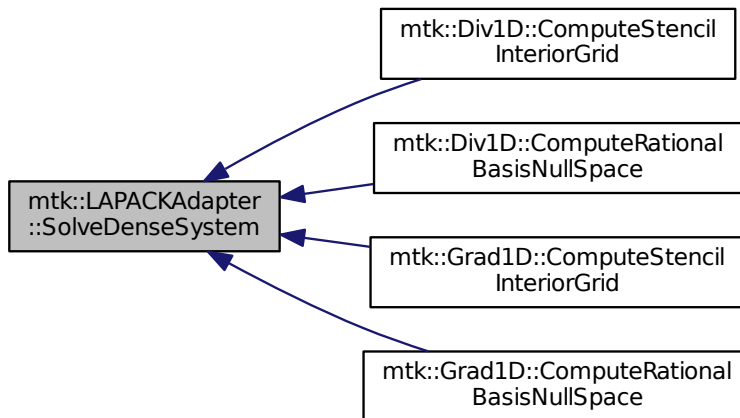
<code>std::bad_alloc</code>
-----------------------------

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:



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

Adapts the MTK to LAPACK's `dgesv_` routine.

**Parameters**

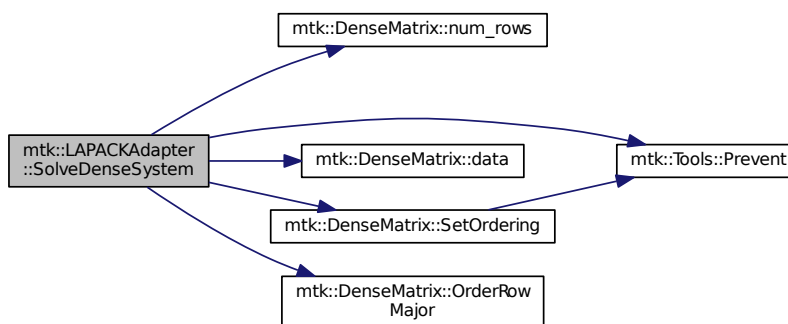
<code>in</code>	<code>matrix</code>	Input matrix.
<code>in</code>	<code>rr</code>	Input right-hand sides matrix.

## Exceptions

<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line 465 of file `mtk_lapack_adapter.cc`.

Here is the call graph for this function:



16.12.2.4 `int mtk::LAPACKAdapter::SolveDenseSystem ( mtk::DenseMatrix & mm, mtk::UniStgGrid1D & rhs )`  
`[static]`

Adapts the MTK to LAPACK's `dgesv_` routine.

## Parameters

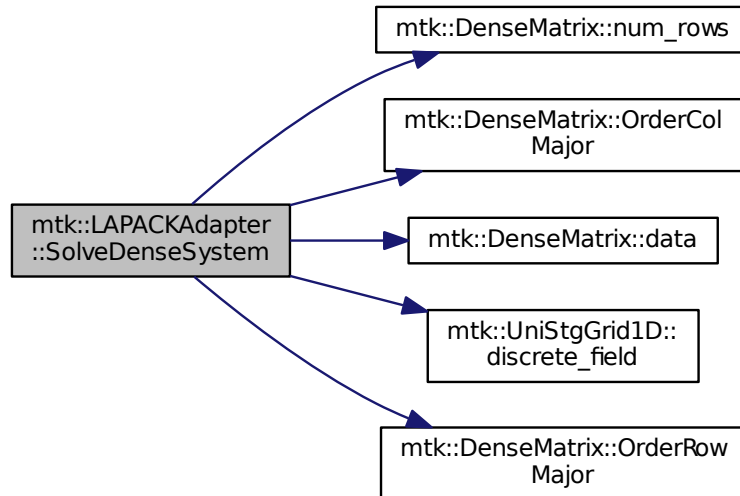
in	<i>matrix</i>	Input matrix.
in	<i>rr</i>	Input right-hand side from info on a grid.

## Exceptions

<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line 517 of file `mtk_lapack_adapter.cc`.

Here is the call graph for this function:



16.12.2.5 `int mtk::LAPACKAdapter::SolveRectangularDenseSystem ( const mtk::DenseMatrix & aa, mtk::Real * ob_, int ob_id_ ) [static]`

Adapts the MTK to LAPACK's routine.

#### Parameters

<code>in, out</code>	<code>matrix</code>	Input matrix.
----------------------	---------------------	---------------

**Returns**

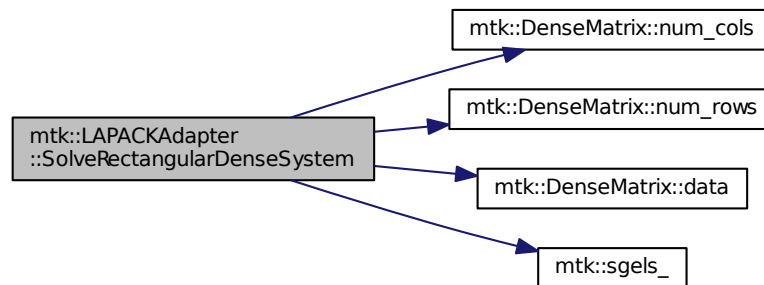
Success of the solution.

**Exceptions**

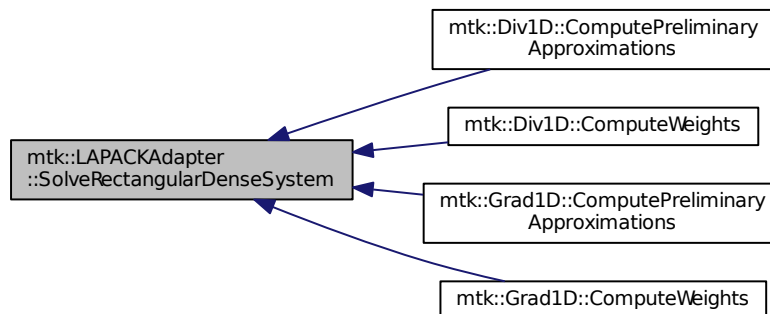
<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line 752 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](#)

## 16.13 mtk::Matrix Class Reference

Definition of the representation of a matrix in the MTK.



```
#include <mtk_matrix.h>
```

Collaboration diagram for mtk::Matrix:

mtk::Matrix
<ul style="list-style-type: none"> <li>- storage_</li> <li>- ordering_</li> <li>- num_rows_</li> <li>- num_cols_</li> <li>- num_values_</li> <li>- ld_</li> <li>- num_zero_</li> <li>- num_non_zero_</li> <li>- num_null_</li> <li>- num_non_null_</li> <li>and 7 more...</li> </ul>
<ul style="list-style-type: none"> <li>+ Matrix()</li> <li>+ Matrix()</li> <li>+ ~Matrix()</li> <li>+ storage()</li> <li>+ ordering()</li> <li>+ num_rows()</li> <li>+ num_cols()</li> <li>+ num_values()</li> <li>+ ld()</li> <li>+ num_zero()</li> <li>and 18 more...</li> </ul>

## 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.*

### 16.13.1 Detailed Description

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

Definition at line 75 of file [mtk\\_matrix.h](#).

### 16.13.2 Constructor & Destructor Documentation

#### 16.13.2.1 mtk::Matrix::Matrix ( )

Definition at line 67 of file [mtk\\_matrix.cc](#).

16.13.2.2 mtk::Matrix::Matrix ( const Matrix & *in* )

## Parameters

<code>in</code>	<code>in</code>	Given matrix.
-----------------	-----------------	---------------

Definition at line 86 of file [mtk\\_matrix.cc](#).

16.13.2.3 `mtk::Matrix::~~Matrix ( )` [noexcept]

Definition at line 105 of file [mtk\\_matrix.cc](#).

### 16.13.3 Member Function Documentation

16.13.3.1 `Real mtk::Matrix::abs_density ( ) const` [noexcept]

See also

[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

## Returns

Absolute density of the matrix.

16.13.3.2 `mtk::Real mtk::Matrix::abs_sparsity ( ) const` [noexcept]

See also

[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

## Returns

Absolute sparsity of the matrix.

Definition at line 177 of file [mtk\\_matrix.cc](#).

16.13.3.3 `int mtk::Matrix::bandwidth ( ) const` [noexcept]

## Returns

Bandwidth of the matrix.

Definition at line 167 of file [mtk\\_matrix.cc](#).

16.13.3.4 `void mtk::Matrix::IncreaseNumNull ( )` [noexcept]

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

Definition at line 274 of file [mtk\\_matrix.cc](#).

16.13.3.5 void mtk::Matrix::IncreaseNumZero ( ) [noexcept]

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

Definition at line 264 of file [mtk\\_matrix.cc](#).

16.13.3.6 int mtk::Matrix::kl ( ) const [noexcept]

Returns

Number of lower diagonals.

Definition at line 157 of file [mtk\\_matrix.cc](#).

16.13.3.7 int mtk::Matrix::ku ( ) const [noexcept]

Returns

Number of upper diagonals.

Definition at line 162 of file [mtk\\_matrix.cc](#).

16.13.3.8 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](#).

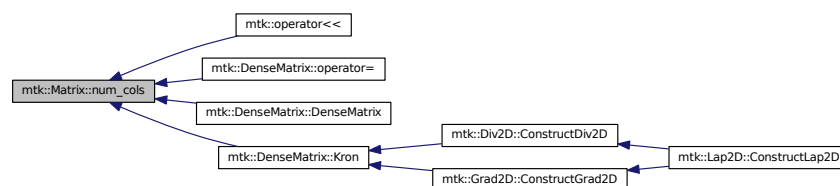
16.13.3.9 int mtk::Matrix::num\_cols ( ) const [noexcept]

Returns

Number of rows of the matrix.

Definition at line 122 of file [mtk\\_matrix.cc](#).

Here is the caller graph for this function:



16.13.3.10 `int mtk::Matrix::num_non_null ( ) const [noexcept]`

See also

[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

Returns

Number of non-null values of the matrix.

Definition at line 152 of file `mtk_matrix.cc`.

16.13.3.11 `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`.

16.13.3.12 `int mtk::Matrix::num_null ( ) const [noexcept]`

See also

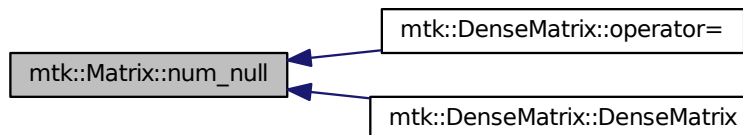
[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

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:



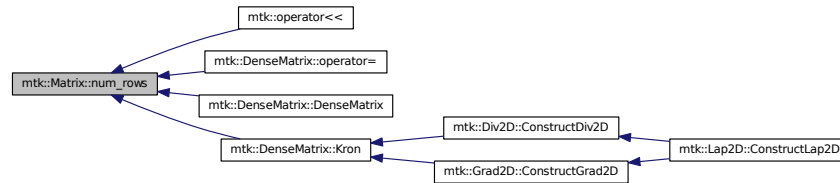
16.13.3.13 `int mtk::Matrix::num_rows ( ) const [noexcept]`

**Returns**

Number of rows of the matrix.

Definition at line 117 of file [mtk\\_matrix.cc](#).

Here is the caller graph for this function:



16.13.3.14 `int mtk::Matrix::num_values ( ) const` [noexcept]

**Returns**

Number of values of the matrix.

Definition at line 127 of file [mtk\\_matrix.cc](#).

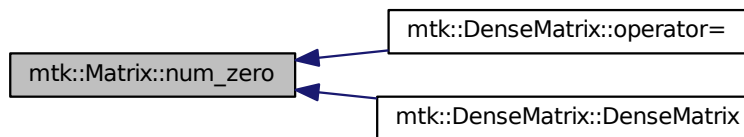
16.13.3.15 `int mtk::Matrix::num_zero ( ) const` [noexcept]

**Returns**

Number of zeros of the matrix.

Definition at line 137 of file [mtk\\_matrix.cc](#).

Here is the caller graph for this function:



16.13.3.16 `mtk::MatrixOrdering mtk::Matrix::ordering ( ) const` [noexcept]

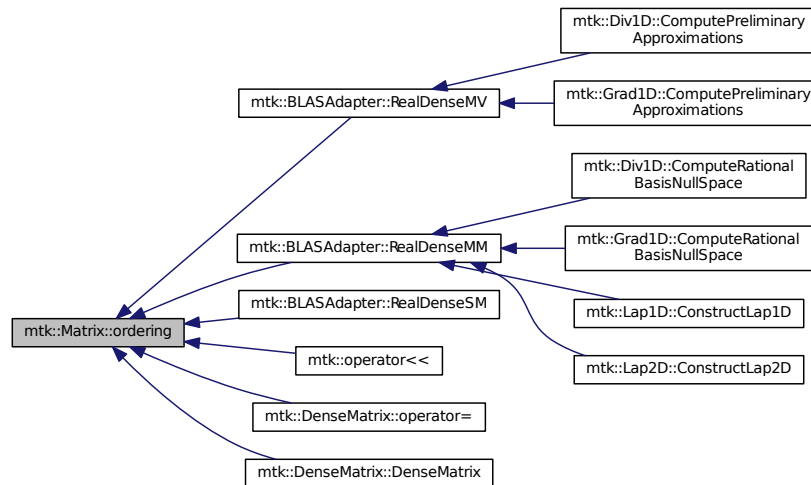


## Returns

Type of ordering of this matrix.

Definition at line 112 of file [mtk\\_matrix.cc](#).

Here is the caller graph for this function:



16.13.3.17 `mtk::Real mtk::Matrix::rel_density ( ) const` [noexcept]

## See also

[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

## Returns

Relative density of the matrix.

Definition at line 172 of file [mtk\\_matrix.cc](#).

16.13.3.18 `mtk::Real mtk::Matrix::rel_sparsity ( ) const` [noexcept]

## See also

[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

## Returns

Relative sparsity of the matrix.

Definition at line 182 of file [mtk\\_matrix.cc](#).

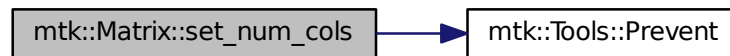
16.13.3.19 `void mtk::Matrix::set_num_cols ( const int & num_cols )` [noexcept]

## Parameters

<i>in</i>	<i>num_cols</i>	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:



16.13.3.20 `void mtk::Matrix::set_num_null ( const int & in ) [noexcept]`

## Parameters

<i>in</i>	<i>in</i>	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:



**16.13.3.21** `void mtk::Matrix::set_num_rows ( const int & num_rows ) [noexcept]`

Parameters

<code>in</code>	<code>num_rows</code>	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:



**16.13.3.22** `void mtk::Matrix::set_num_zero ( const int & in ) [noexcept]`

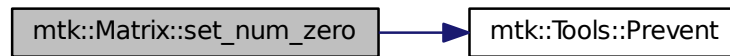
Parameters

<code>in</code>	<code>in</code>	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:



**16.13.3.23** `void mtk::Matrix::set_ordering ( const MatrixOrdering & oo ) [noexcept]`

See also

[MatrixOrdering](#)

#### Parameters

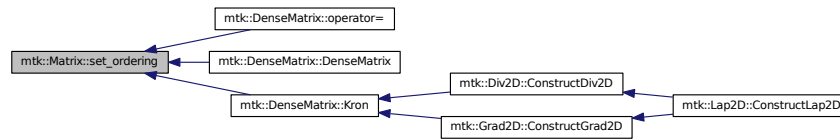
<code>in</code>	<code>oo</code>	Ordering of the matrix.
-----------------	-----------------	-------------------------

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:



**16.13.3.24** void mtk::Matrix::set\_storage ( const MatrixStorage & tt ) [noexcept]

See also

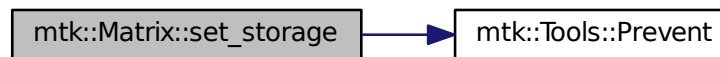
[MatrixStorage](#)

Parameters

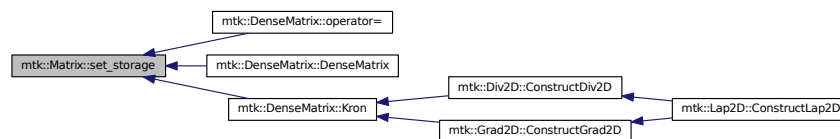
in	tt	Type of the matrix storage.
----	----	-----------------------------

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:



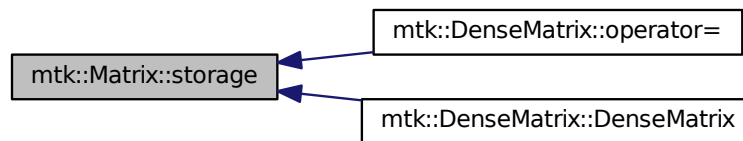
**16.13.3.25** mtk::MatrixStorage mtk::Matrix::storage ( ) const [noexcept]

**Returns**

Type of storage of this matrix.

Definition at line 107 of file [mtk\\_matrix.cc](#).

Here is the caller graph for this function:

**16.13.4 Member Data Documentation****16.13.4.1 Real mtk::Matrix::abs\_density\_ [private]**

Definition at line 296 of file [mtk\\_matrix.h](#).

**16.13.4.2 Real mtk::Matrix::abs\_sparsity\_ [private]**

Definition at line 298 of file [mtk\\_matrix.h](#).

**16.13.4.3 int mtk::Matrix::bandwidth\_ [private]**

Definition at line 294 of file [mtk\\_matrix.h](#).

**16.13.4.4 int mtk::Matrix::kl\_ [private]**

Definition at line 292 of file [mtk\\_matrix.h](#).

**16.13.4.5 int mtk::Matrix::ku\_ [private]**

Definition at line 293 of file [mtk\\_matrix.h](#).

**16.13.4.6 int mtk::Matrix::ld\_ [private]**

Definition at line 285 of file [mtk\\_matrix.h](#).

**16.13.4.7 int mtk::Matrix::num\_cols\_ [private]**

Definition at line 283 of file [mtk\\_matrix.h](#).

16.13.4.8 `int mtk::Matrix::num_non_null_ [private]`

Definition at line 290 of file [mtk\\_matrix.h](#).

16.13.4.9 `int mtk::Matrix::num_non_zero_ [private]`

Definition at line 288 of file [mtk\\_matrix.h](#).

16.13.4.10 `int mtk::Matrix::num_null_ [private]`

Definition at line 289 of file [mtk\\_matrix.h](#).

16.13.4.11 `int mtk::Matrix::num_rows_ [private]`

Definition at line 282 of file [mtk\\_matrix.h](#).

16.13.4.12 `int mtk::Matrix::num_values_ [private]`

Definition at line 284 of file [mtk\\_matrix.h](#).

16.13.4.13 `int mtk::Matrix::num_zero_ [private]`

Definition at line 287 of file [mtk\\_matrix.h](#).

16.13.4.14 `MatrixOrdering mtk::Matrix::ordering_ [private]`

Definition at line 280 of file [mtk\\_matrix.h](#).

16.13.4.15 `Real mtk::Matrix::rel_density_ [private]`

Definition at line 297 of file [mtk\\_matrix.h](#).

16.13.4.16 `Real mtk::Matrix::rel_sparsity_ [private]`

Definition at line 299 of file [mtk\\_matrix.h](#).

16.13.4.17 `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:

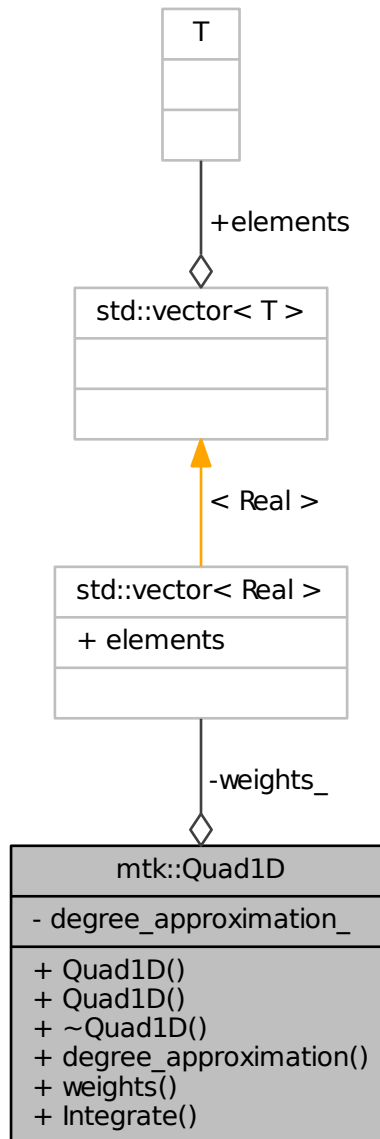
- [include/mtk\\_matrix.h](#)
- [src/mtk\\_matrix.cc](#)

## 16.14 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.*

### 16.14.1 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](#).

### 16.14.2 Constructor & Destructor Documentation

16.14.2.1 [mtk::Quad1D::Quad1D](#) ( )

16.14.2.2 [mtk::Quad1D::Quad1D](#) ( const [Quad1D](#) & *quad* )

#### Parameters

<i>in</i>	<i>div</i>	Given quadrature.
-----------	------------	-------------------

16.14.2.3 `mtk::Quad1D::~~Quad1D ( )`

### 16.14.3 Member Function Documentation

16.14.3.1 `int mtk::Quad1D::degree_approximation ( ) const`

#### Returns

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

16.14.3.2 `Real mtk::Quad1D::Integrate ( Real(*) (Real xx) Integrand, UniStgGrid1D grid ) const`

#### Parameters

<code>in</code>	<i>Integrand</i>	Real-valued function to integrate.
<code>in</code>	<i>grid</i>	Given integration domain.

#### Returns

Result of the integration.

16.14.3.3 `Real* mtk::Quad1D::weights ( ) const`

#### Returns

Collection of weights.

### 16.14.4 Friends And Related Function Documentation

16.14.4.1 `std::ostream& operator<< ( std::ostream & stream, Quad1D & in )` [`friend`]

### 16.14.5 Member Data Documentation

16.14.5.1 `int mtk::Quad1D::degree_approximation_` [`private`]

Definition at line 124 of file [mtk\\_quad\\_1d.h](#).

16.14.5.2 `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:

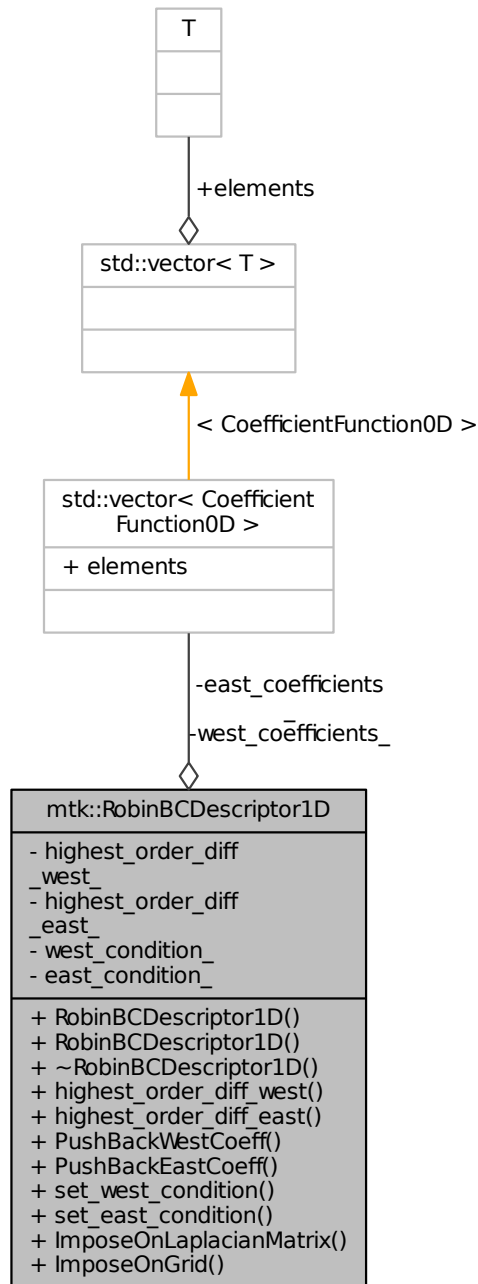
- [include/mtk\\_quad\\_1d.h](#)

## 16.15 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.*

### 16.15.1 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:

$$\begin{aligned}\delta_a(a, t)u(a, t) - \eta_a(a, t)u'(a, t) &= \beta_a(a, t), \\ \delta_b(b, t)u(b, t) + \eta_b(b, t)u'(b, t) &= \beta_b(b, t).\end{aligned}$$

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](#).

## 16.15.2 Constructor & Destructor Documentation

### 16.15.2.1 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D ( )

Definition at line 93 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.cc](#).

### 16.15.2.2 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D ( const RobinBCDescriptor1D & desc )

Parameters

<i>in</i>	<i>desc</i>	Given 1D descriptor.
-----------	-------------	----------------------

Definition at line 99 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.cc](#).

### 16.15.2.3 mtk::RobinBCDescriptor1D::~~RobinBCDescriptor1D ( ) [noexcept]

Definition at line 106 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.cc](#).

## 16.15.3 Member Function Documentation

### 16.15.3.1 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](#).

### 16.15.3.2 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](#).

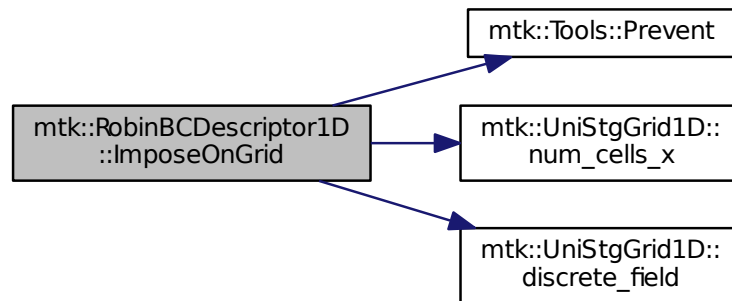
16.15.3.3 void mtk::RobinBCDescriptor1D::ImposeOnGrid ( UniStgGrid1D & *grid*, const Real & *time* = mtk::kZero ) const

#### Parameters

in, out	<i>grid</i>	Grid upon which impose the desired boundary condition.
in	<i>time</i>	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:



16.15.3.4 bool mtk::RobinBCDescriptor1D::ImposeOnLaplacianMatrix ( const Lap1D & *lap*, mtk::DenseMatrix & *matrix*, const Real & *time* = mtk::kZero ) const

#### Parameters

in	<i>lap</i>	Operator in the <a href="#">Matrix</a> .
in, out	<i>matrix</i>	Input Laplacian operator.
in	<i>time</i>	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.

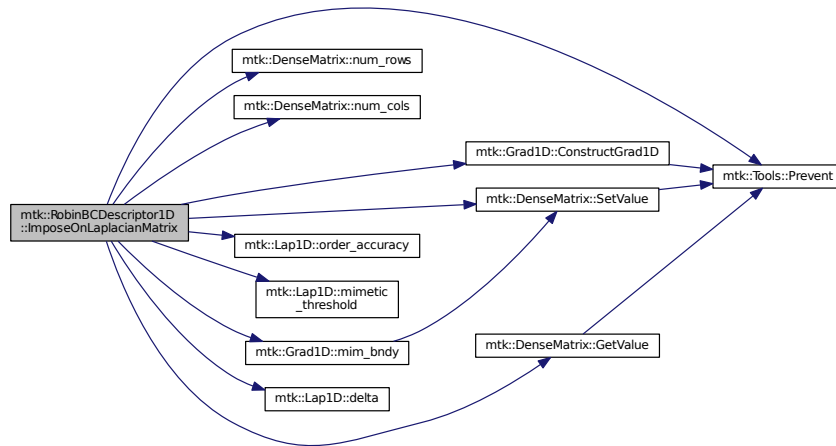
2.4.1. Get gradient coefficient and scale it.

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:



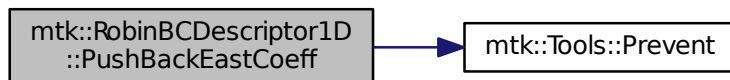
16.15.3.5 void mtk::RobinBCDescriptor1D::PushBackEastCoeff ( mtk::CoefficientFunction0D ce )

## Parameters

<i>in</i>	<i>ce</i>	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:



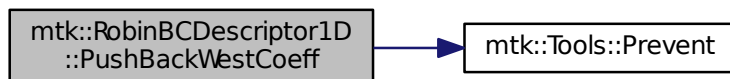
### 16.15.3.6 void mtk::RobinBCDescriptor1D::PushBackWestCoeff ( mtk::CoefficientFunction0D *cw* )

## Parameters

<i>in</i>	<i>cw</i>	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:



### 16.15.3.7 void mtk::RobinBCDescriptor1D::set\_east\_condition ( Real(\*) (const Real &tt) *east\_condition* ) [noexcept]

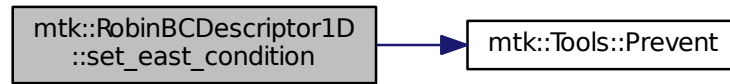
## Parameters

<i>in</i>	<i>east_condition</i>	$\beta_e(y, t) : \Omega \mapsto \mathbb{R}$ .
-----------	-----------------------	---

Definition at line 156 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.cc](#).



Here is the call graph for this function:



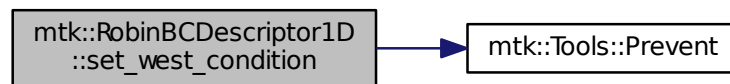
16.15.3.8 void mtk::RobinBCDescriptor1D::set\_west\_condition ( Real(\*) (const Real &tt) west\_condition ) [noexcept]

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:



## 16.15.4 Member Data Documentation

16.15.4.1 std::vector<CoefficientFunction0D> mtk::RobinBCDescriptor1D::east\_coefficients\_ [private]

Definition at line 237 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.h](#).

16.15.4.2 Real(\*) mtk::RobinBCDescriptor1D::east\_condition\_ (const Real &tt) [private]

Definition at line 240 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.h](#).

16.15.4.3 int mtk::RobinBCDescriptor1D::highest\_order\_diff\_east\_ [private]

Definition at line 234 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.h](#).

16.15.4.4 int mtk::RobinBCDescriptor1D::highest\_order\_diff\_west\_ [private]

Definition at line 233 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.h](#).

16.15.4.5 `std::vector<CoefficientFunction0D> mtk::RobinBCDescriptor1D::west_coefficients_` [private]

Definition at line 236 of file [mtk\\_robin\\_bc\\_descriptor\\_1d.h](#).

16.15.4.6 `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:

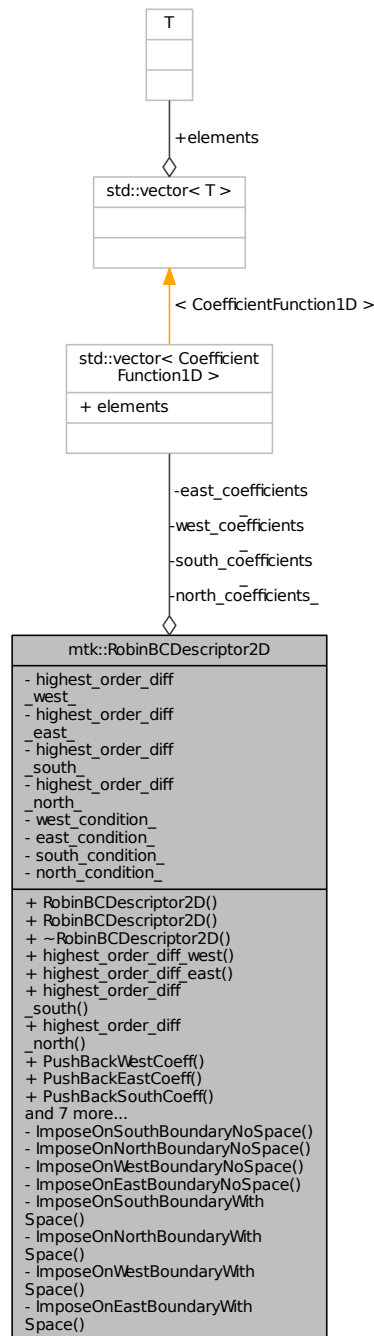
- [include/mtk\\_robin\\_bc\\_descriptor\\_1d.h](#)
- [src/mtk\\_robin\\_bc\\_descriptor\\_1d.cc](#)

## 16.16 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.*

### 16.16.1 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](#).

### 16.16.2 Constructor & Destructor Documentation

16.16.2.1 `mtk::RobinBCDescriptor2D::RobinBCDescriptor2D ( )`

Definition at line 84 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.cc](#).

16.16.2.2 `mtk::RobinBCDescriptor2D::RobinBCDescriptor2D ( const RobinBCDescriptor2D & desc )`

Parameters

<i>in</i>	<i>desc</i>	Given 2D descriptor.
-----------	-------------	----------------------

Definition at line 94 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.cc](#).

16.16.2.3 `mtk::RobinBCDescriptor2D::~~RobinBCDescriptor2D ( ) [noexcept]`

Definition at line 105 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.cc](#).

### 16.16.3 Member Function Documentation

16.16.3.1 `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](#).

16.16.3.2 `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](#).

16.16.3.3 `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](#).

16.16.3.4 `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](#).

16.16.3.5 `bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryNoSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` `[private]`

#### Parameters

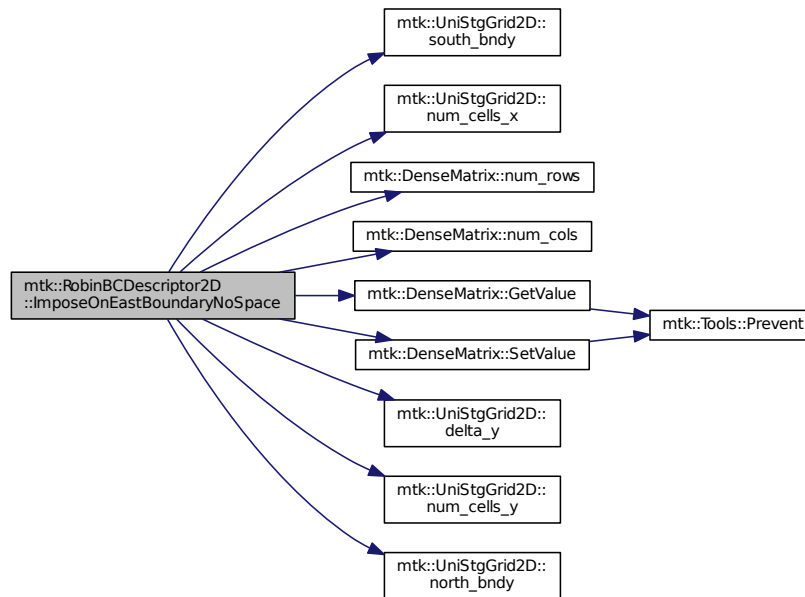
<code>in</code>	<code>lap</code>	Laplacian operator on the matrix.
<code>in</code>	<code>grid</code>	Grid upon which impose the desired boundary condition.
<code>in, out</code>	<code>matrix</code>	Input matrix with the Laplacian operator.
<code>in</code>	<code>time</code>	Current time snapshot. Default 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:



16.16.3.6 `bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryWithSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` [private]

#### Parameters

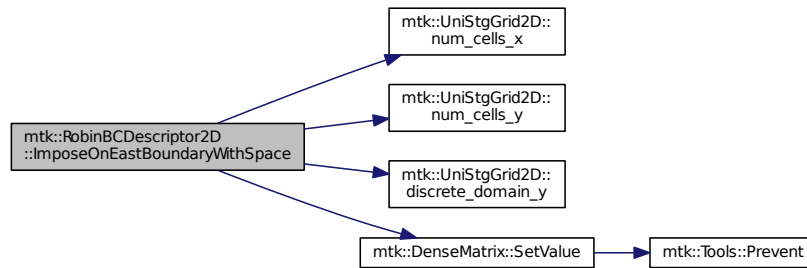
in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	Current time snapshot. Default is kZero.

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:



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

#### Parameters

in, out	<i>grid</i>	Grid upon which impose the desired boundary condition.
in	<i>time</i>	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.

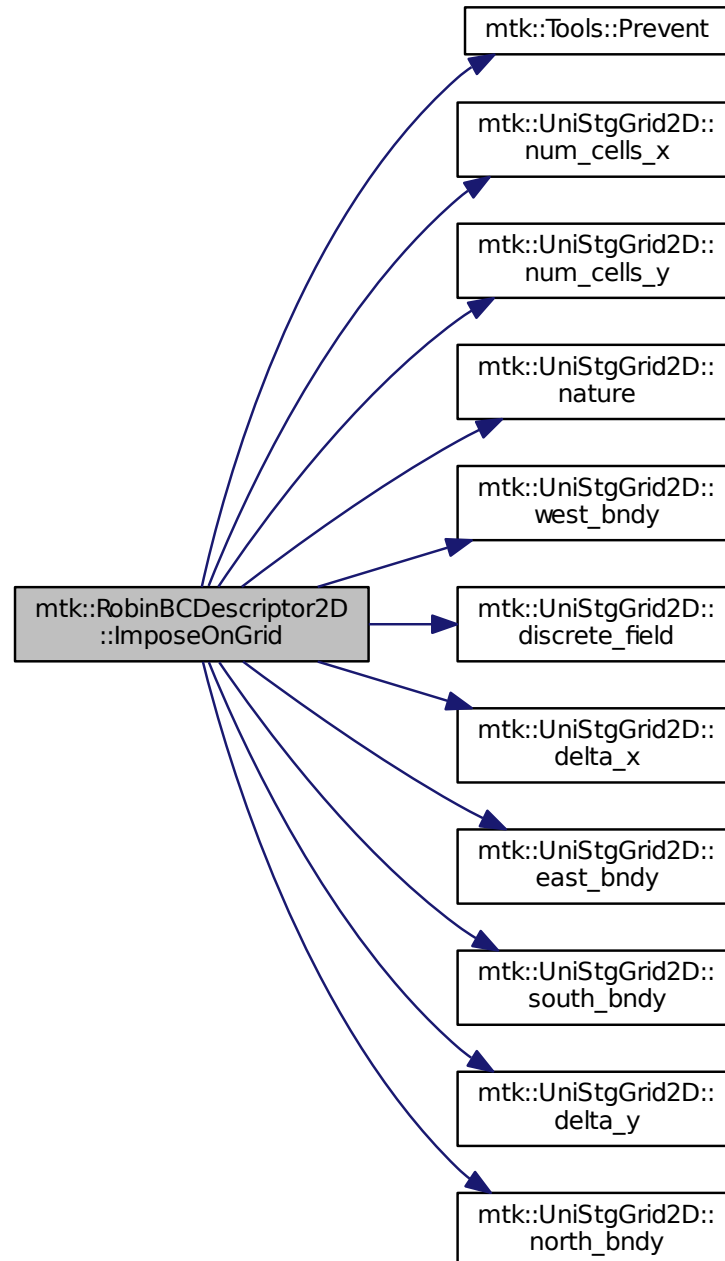
1.4.3. Impose north-east corner.

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:



16.16.3.8 `bool mtk::RobinBCDescriptor2D::ImposeOnLaplacianMatrix ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const`

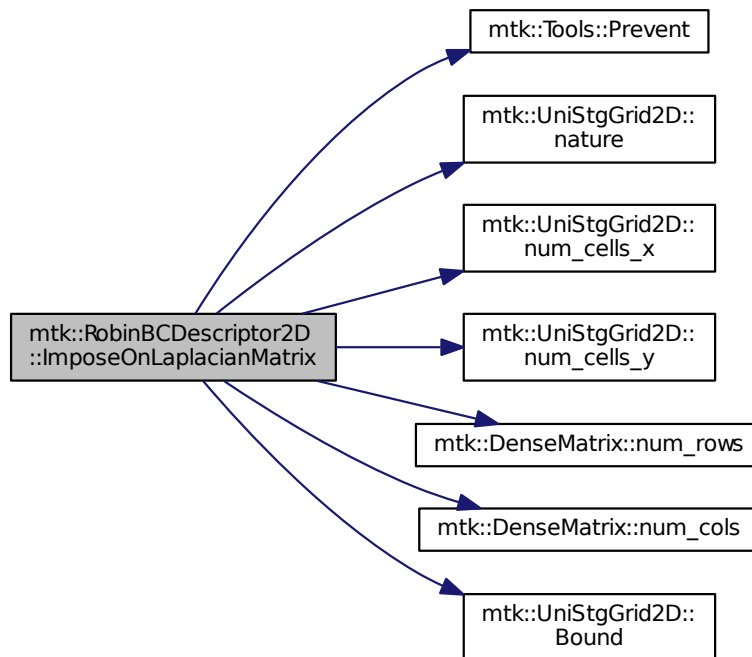
#### Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	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:



16.16.3.9 `bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryNoSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` `[private]`

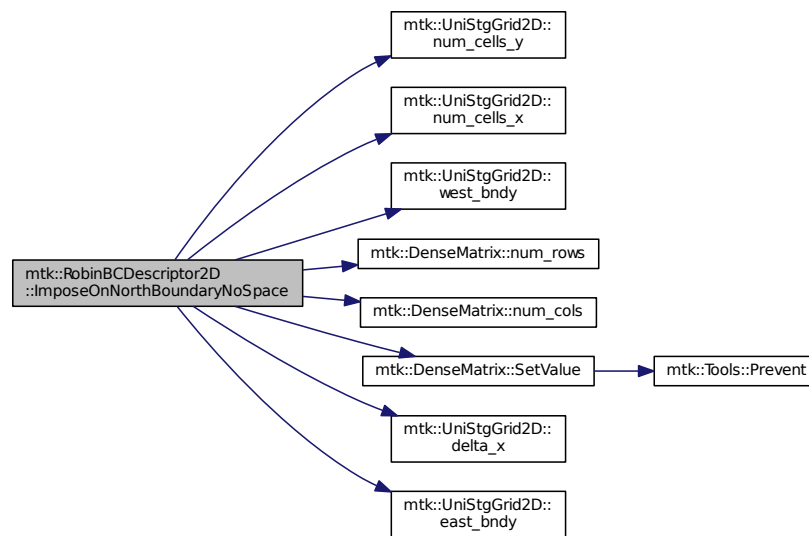
#### Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	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:



16.16.3.10 `bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryWithSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` [private]

#### Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	Current time snapshot. Default is kZero.

1. Impose Dirichlet condition.

For each entry on the diagonal:

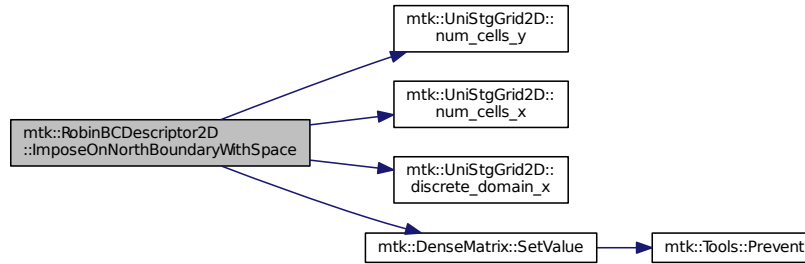
Evaluate next set spatial coordinates to evaluate the coefficient.

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:



16.16.3.11 `bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryNoSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const [private]`

#### Parameters

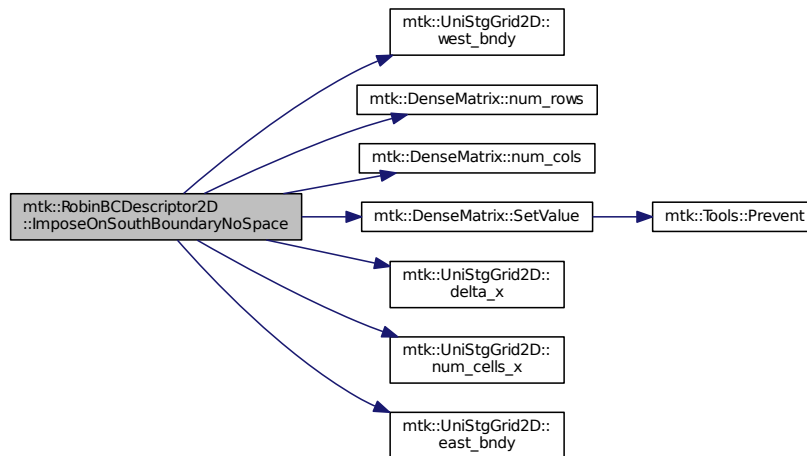
in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	Current time snapshot. Default is kZero.

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:



16.16.3.12 `bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryWithSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const [private]`

#### Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	Current time snapshot. Default is kZero.

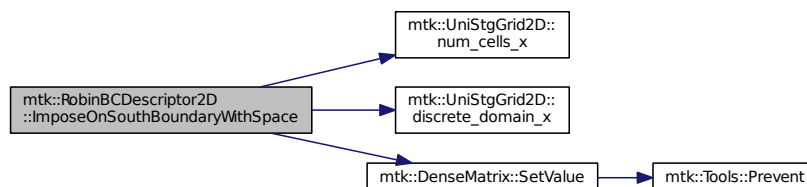
1. Impose the Dirichlet condition first.

**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:



16.16.3.13 `bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryNoSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` [private]

#### Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	Current time snapshot. Default is kZero.

1. Impose the Dirichlet condition first.

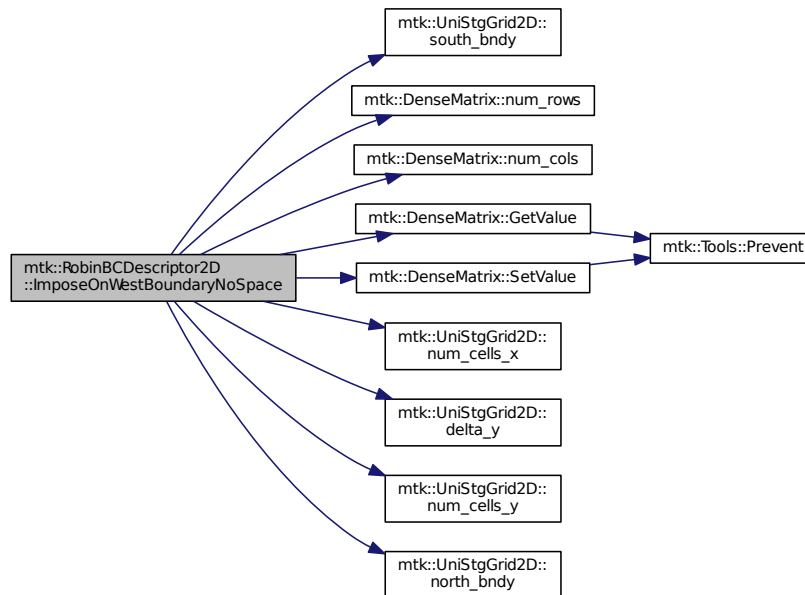
#### Note

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:



16.16.3.14 `bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryWithSpace ( const Lap2D & lap, const UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const Real & time = kZero ) const` [private]

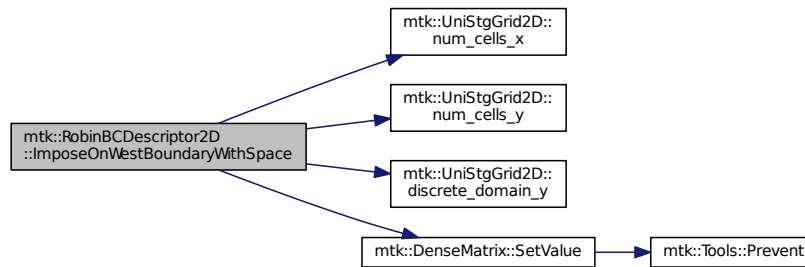
## Parameters

in	<i>lap</i>	Laplacian operator on the matrix.
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input matrix with the Laplacian operator.
in	<i>time</i>	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:



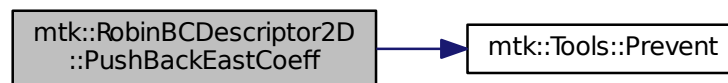
16.16.3.15 void mtk::RobinBCDescriptor2D::PushBackEastCoeff ( mtk::CoefficientFunction1D ce )

## Parameters

in	<i>cw</i>	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:



16.16.3.16 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff ( mtk::CoefficientFunction1D cn )

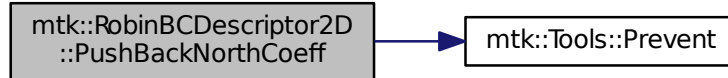


## Parameters

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:



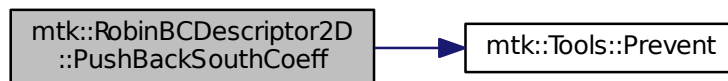
16.16.3.17 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff ( mtk::CoefficientFunction1D cs )

## 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:



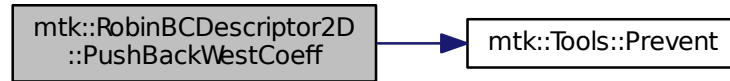
16.16.3.18 void mtk::RobinBCDescriptor2D::PushBackWestCoeff ( mtk::CoefficientFunction1D cw )

## 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:



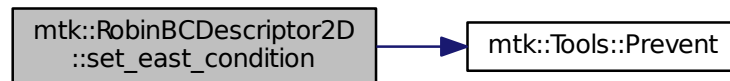
16.16.3.19 void mtk::RobinBCDescriptor2D::set\_east\_condition ( Real(\*) (const Real &yy, const Real &tt) east\_condition )  
[noexcept]

#### 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:



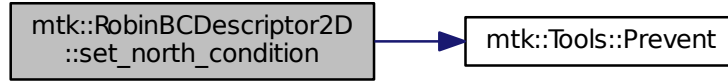
16.16.3.20 void mtk::RobinBCDescriptor2D::set\_north\_condition ( Real(\*) (const Real &xx, const Real &tt) north\_condition )  
[noexcept]

#### 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:



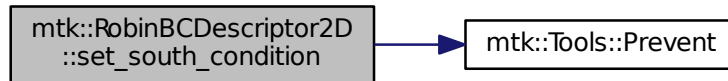
**16.16.3.21** void mtk::RobinBCDescriptor2D::set\_south\_condition ( Real(\*) (const Real &xx, const Real &tt) south\_condition )  
[noexcept]

#### 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:



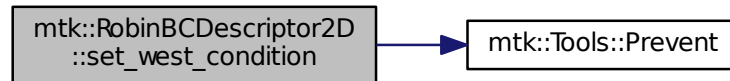
**16.16.3.22** void mtk::RobinBCDescriptor2D::set\_west\_condition ( Real(\*) (const Real &yy, const Real &tt) west\_condition )  
[noexcept]

#### 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:



#### 16.16.4 Member Data Documentation

16.16.4.1 `std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::east_coefficients_` [private]

Definition at line 367 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.2 `Real(* mtk::RobinBCDescriptor2D::east_condition_)(const Real &xx, const Real &tt)` [private]

Definition at line 372 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.3 `int mtk::RobinBCDescriptor2D::highest_order_diff_east_` [private]

Definition at line 362 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.4 `int mtk::RobinBCDescriptor2D::highest_order_diff_north_` [private]

Definition at line 364 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.5 `int mtk::RobinBCDescriptor2D::highest_order_diff_south_` [private]

Definition at line 363 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.6 `int mtk::RobinBCDescriptor2D::highest_order_diff_west_` [private]

Definition at line 361 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.7 `std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::north_coefficients_` [private]

Definition at line 369 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.8 `Real(* mtk::RobinBCDescriptor2D::north_condition_)(const Real &yy, const Real &tt)` [private]

Definition at line 374 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.9 `std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::south_coefficients_` [private]

Definition at line 368 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.10 `Real(* mtk::RobinBCDescriptor2D::south_condition_)(const Real &yy, const Real &tt)` [private]

Definition at line 373 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.11 `std::vector<CoefficientFunction1D> mtk::RobinBCDescriptor2D::west_coefficients_` [private]

Definition at line 366 of file [mtk\\_robin\\_bc\\_descriptor\\_2d.h](#).

16.16.4.12 `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:

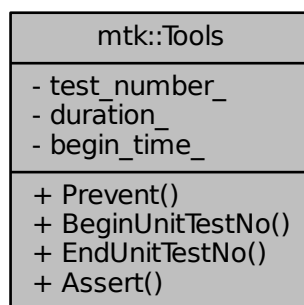
- [include/mtk\\_robin\\_bc\\_descriptor\\_2d.h](#)
- [src/mtk\\_robin\\_bc\\_descriptor\\_2d.cc](#)

## 16.17 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.*

### 16.17.1 Detailed Description

Basic tools to ensure execution correctness.

Definition at line 78 of file [mtk\\_tools.h](#).

### 16.17.2 Member Function Documentation

16.17.2.1 void [mtk::Tools::Assert](#) ( const bool & *condition* ) [static], [noexcept]

#### Parameters

in	<i>condition</i>	Condition to be asserted.
----	------------------	---------------------------

Definition at line 109 of file [mtk\\_tools.cc](#).

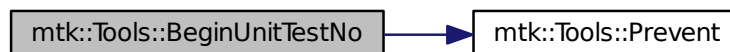
16.17.2.2 void [mtk::Tools::BeginUnitTestNo](#) ( const int & *nn* ) [static], [noexcept]

#### Parameters

in	<i>nn</i>	Number of the test.
----	-----------	---------------------

Definition at line 88 of file [mtk\\_tools.cc](#).

Here is the call graph for this function:



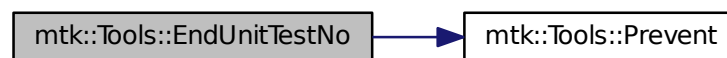
16.17.2.3 void mtk::Tools::EndUnitTestNo ( const int & *nn* ) [static], [noexcept]

#### Parameters

in	<i>nn</i>	Number of the test.
----	-----------	---------------------

Definition at line 100 of file [mtk\\_tools.cc](#).

Here is the call graph for this function:



16.17.2.4 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>

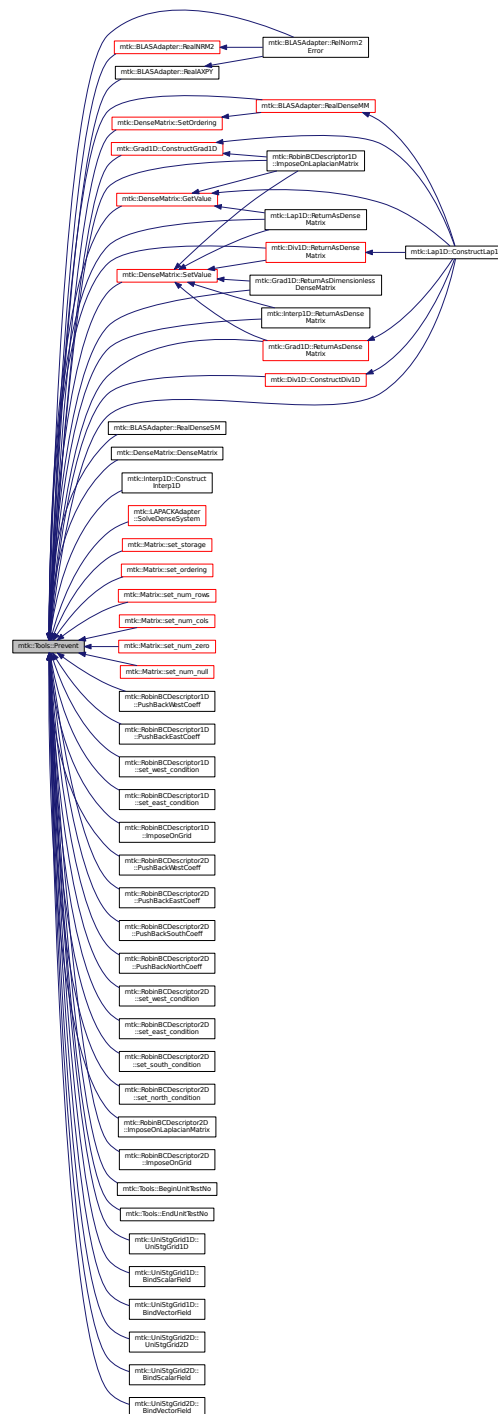
#### Parameters

in	<i>complement</i>	Complement of desired pre-condition.
in	<i>fname</i>	Name of the file being checked.
in	<i>lineno</i>	Number of the line where the check is executed.
in	<i>fxname</i>	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](#).

Here is the caller graph for this function:



### 16.17.3 Member Data Documentation



16.17.3.1 `clock_t mtk::Tools::begin_time_` `[static], [private]`

Definition at line 121 of file [mtk\\_tools.h](#).

16.17.3.2 `mtk::Real mtk::Tools::duration_` `[static], [private]`

Definition at line 119 of file [mtk\\_tools.h](#).

16.17.3.3 `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:

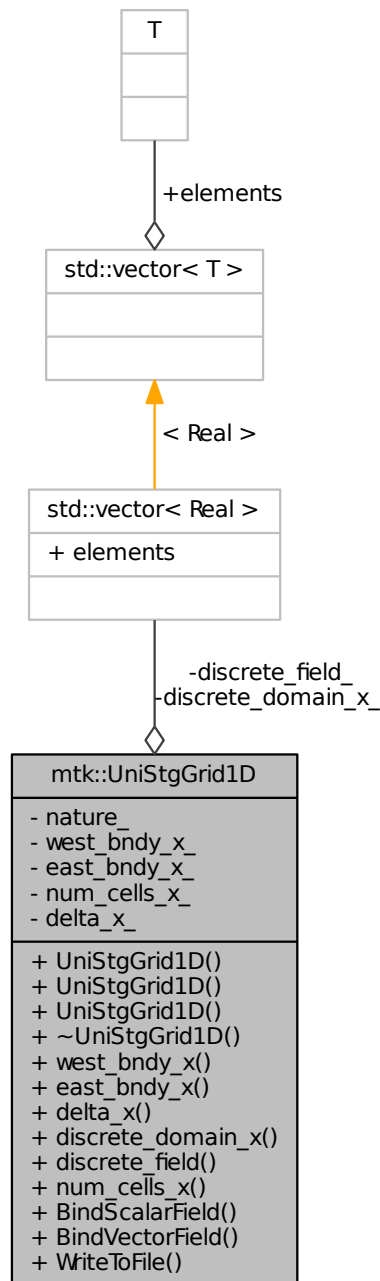
- [include/mtk\\_tools.h](#)
- [src/mtk\\_tools.cc](#)

## 16.18 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::Field](#) &nature &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  $\Delta x$ .*

- 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.*

### 16.18.1 Detailed Description

Uniform 1D Staggered Grid.

Definition at line 77 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

### 16.18.2 Constructor & Destructor Documentation

#### 16.18.2.1 `mtk::UniStgGrid1D::UniStgGrid1D ( )`

Definition at line 99 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

#### 16.18.2.2 `mtk::UniStgGrid1D::UniStgGrid1D ( const UniStgGrid1D & grid )`

Parameters

in	<i>grid</i>	Given grid.
----	-------------	-------------

Definition at line 108 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

#### 16.18.2.3 `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

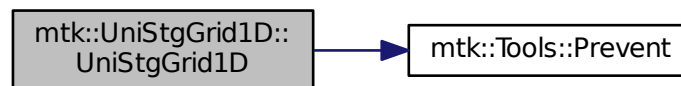
in	<i>west_bndy_x</i>	Coordinate for the west boundary.
in	<i>east_bndy_x</i>	Coordinate for the east boundary.
in	<i>num_cells_x</i>	Number of cells of the required grid.
in	<i>nature</i>	Nature of the discrete field to hold.

See also

[mtk::FieldNature](#)

Definition at line 124 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

Here is the call graph for this function:



#### 16.18.2.4 `mtk::UniStgGrid1D::~~UniStgGrid1D ( )`

Definition at line 144 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

### 16.18.3 Member Function Documentation

#### 16.18.3.1 void mtk::UniStgGrid1D::BindScalarField ( *Real*(\*) (const *Real* &xx) *ScalarField* )

##### Parameters

in	<i>ScalarField</i>	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:



#### 16.18.3.2 void mtk::UniStgGrid1D::BindVectorField ( *Real*(\*)(*Real* xx) *VectorField* )

We assume the field to be of the form:

$$\mathbf{v}(x) = v(x)\hat{\mathbf{i}}$$

##### Parameters

in	<i>VectorField</i>	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:



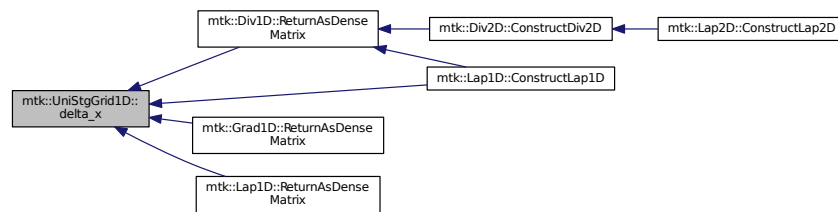
### 16.18.3.3 `mtk::Real mtk::UniStgGrid1D::delta_x ( ) const`

#### Returns

Computed  $\Delta x$ .

Definition at line 156 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

Here is the caller graph for this function:



### 16.18.3.4 `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](#).

### 16.18.3.5 `mtk::Real * mtk::UniStgGrid1D::discrete_field ( )`

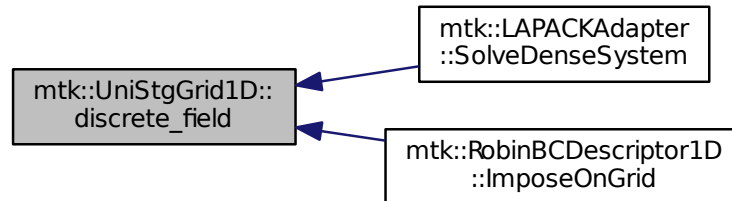
**Returns**

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:

**16.18.3.6 mtk::Real mtk::UniStgGrid1D::east\_bndy\_x ( ) const****Returns**

East boundary spatial coordinate.

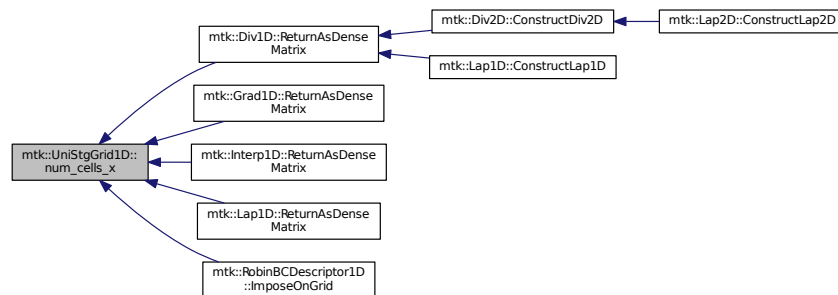
Definition at line 151 of file [mtk\\_uni\\_stg\\_grid\\_1d.cc](#).

**16.18.3.7 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:



16.18.3.8 `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](#).

16.18.3.9 `bool mtk::UniStgGrid1D::WriteToFile ( std::string filename, std::string space_name, std::string field_name ) const`

#### Parameters

in	<i>filename</i>	Name of the output file.
in	<i>space_name</i>	Name for the first column of the data.
in	<i>field_name</i>	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](#).

## 16.18.4 Friends And Related Function Documentation

16.18.4.1 `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](#).

## 16.18.5 Member Data Documentation

16.18.5.1 `Real mtk::UniStgGrid1D::delta_x_ [private]`

Definition at line 200 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

16.18.5.2 `std::vector<Real> mtk::UniStgGrid1D::discrete_domain_x_ [private]`

Definition at line 194 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

16.18.5.3 `std::vector<Real> mtk::UniStgGrid1D::discrete_field_ [private]`

Definition at line 195 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).



#### 16.18.5.4 Real mtk::UniStgGrid1D::east\_bndy\_x\_ [private]

Definition at line 198 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

#### 16.18.5.5 FieldNature mtk::UniStgGrid1D::nature\_ [private]

Definition at line 192 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

#### 16.18.5.6 Real mtk::UniStgGrid1D::num\_cells\_x\_ [private]

Definition at line 199 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

#### 16.18.5.7 Real mtk::UniStgGrid1D::west\_bndy\_x\_ [private]

Definition at line 197 of file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

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

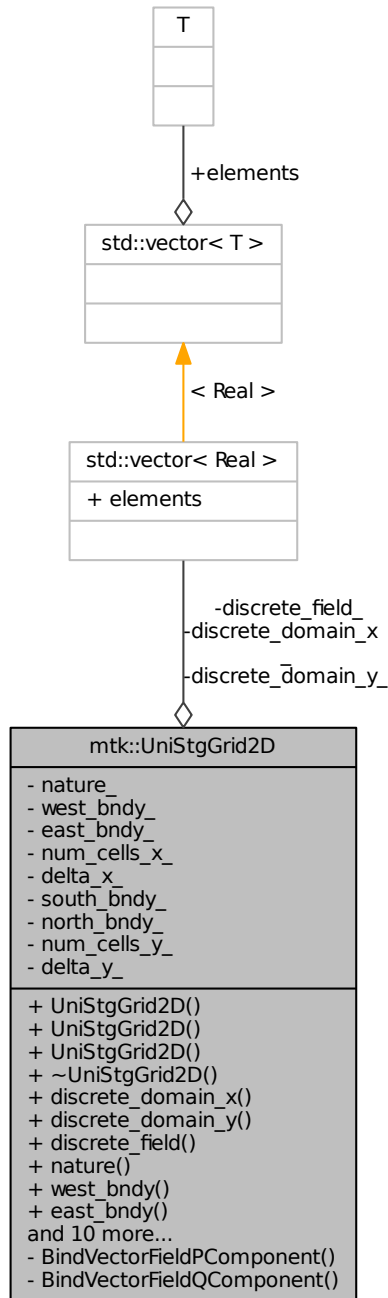
- [include/mtk\\_uni\\_stg\\_grid\\_1d.h](#)
- [src/mtk\\_uni\\_stg\\_grid\\_1d.cc](#)

## 16.19 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  $\Delta x$ .*

- **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  $\Delta y$ .*

- bool **Bound** () const

*Have any field been bound to 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.*

### 16.19.1 Detailed Description

Uniform 2D Staggered Grid.

Definition at line 79 of file `mtk_uni_stg_grid_2d.h`.

## 16.19.2 Constructor & Destructor Documentation

### 16.19.2.1 mtk::UniStgGrid2D::UniStgGrid2D ( )

Definition at line 131 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

### 16.19.2.2 mtk::UniStgGrid2D::UniStgGrid2D ( const UniStgGrid2D & grid )

Parameters

in	<i>grid</i>	Given grid.
----	-------------	-------------

Definition at line 145 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

### 16.19.2.3 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	<i>west_bndy_x</i>	Coordinate for the west boundary.
in	<i>east_bndy_x</i>	Coordinate for the east boundary.
in	<i>num_cells_x</i>	Number of cells of the required grid.
in	<i>south_bndy_y</i>	Coordinate for the west boundary.
in	<i>north_bndy_y</i>	Coordinate for the east boundary.
in	<i>num_cells_y</i>	Number of cells of the required grid.
in	<i>nature</i>	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:



### 16.19.2.4 mtk::UniStgGrid2D::~~UniStgGrid2D ( )

Definition at line 203 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

### 16.19.3 Member Function Documentation

16.19.3.1 void mtk::UniStgGrid2D::BindScalarField ( Real(\*) (const Real &xx, const Real &yy) *ScalarField* )

#### Parameters

in	<i>ScalarField</i>	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 270 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

Here is the call graph for this function:



16.19.3.2 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:

$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

#### Parameters

in	<i>VectorFieldPComponent</i>	Pointer to the function implementing the $p$ component of the vector field.
in	<i>VectorFieldQComponent</i>	Pointer to the function implementing the $q$ component of the vector field.

Definition at line 418 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

Here is the call graph for this function:



16.19.3.3 void mtk::UniStgGrid2D::BindVectorFieldPComponent ( Real(\*) (const Real &xx, const Real &yy)  
VectorFieldPComponent ) [private]

We assume the field to be of the form:

$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

#### Parameters

in	<i>BindVectorFieldPComponent</i>	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 325 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

16.19.3.4 void mtk::UniStgGrid2D::BindVectorFieldQComponent ( Real(\*) (const Real &xx, const Real &yy)  
VectorFieldQComponent ) [private]

We assume the field to be of the form:

$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

#### Parameters

in	<i>BindVectorFieldQComponent</i>	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 390 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

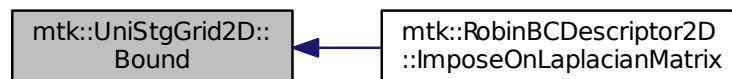
16.19.3.5 `bool mtk::UniStgGrid2D::Bound ( ) const`

#### 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:



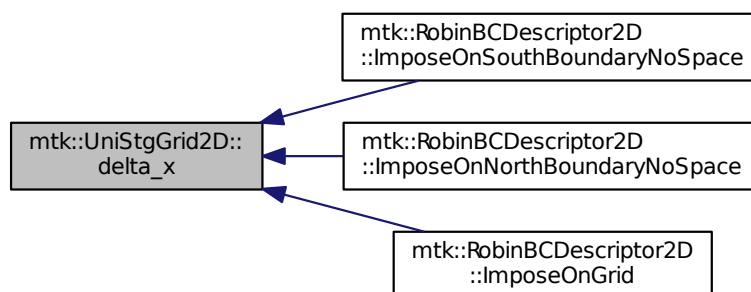
16.19.3.6 `mtk::Real mtk::UniStgGrid2D::delta_x ( ) const`

#### Returns

Computed  $\Delta x$ .

Definition at line 225 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

Here is the caller graph for this function:



16.19.3.7 `mtk::Real mtk::UniStgGrid2D::delta_y ( ) const`

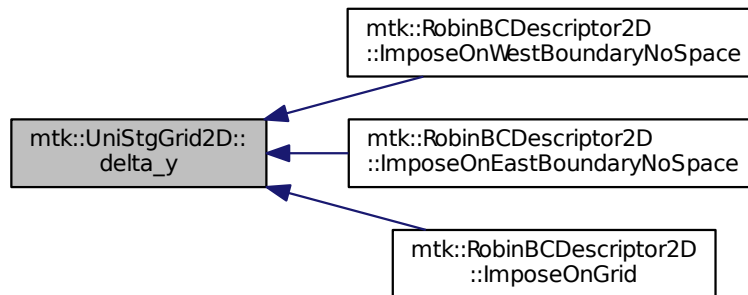


## Returns

Computed  $\Delta y$ .

Definition at line 250 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

Here is the caller graph for this function:



### 16.19.3.8 `const mtk::Real * mtk::UniStgGrid2D::discrete_domain_x ( ) const`

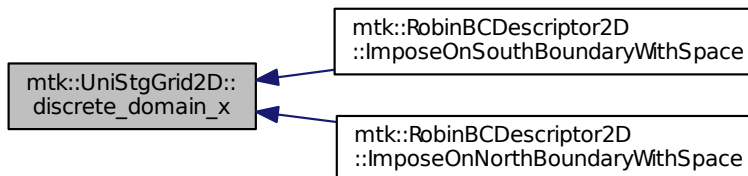
## Returns

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:



### 16.19.3.9 `const mtk::Real * mtk::UniStgGrid2D::discrete_domain_y ( ) const`

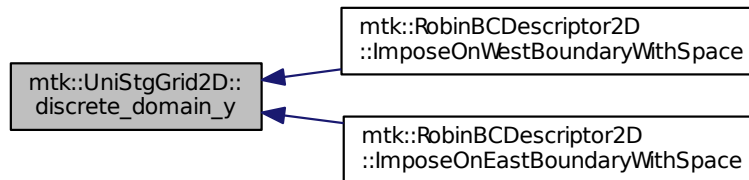
## Returns

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:



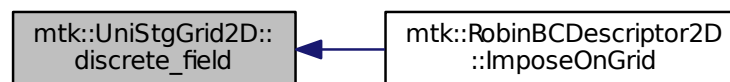
### 16.19.3.10 `mtk::Real * mtk::UniStgGrid2D::discrete_field ( )`

## 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:



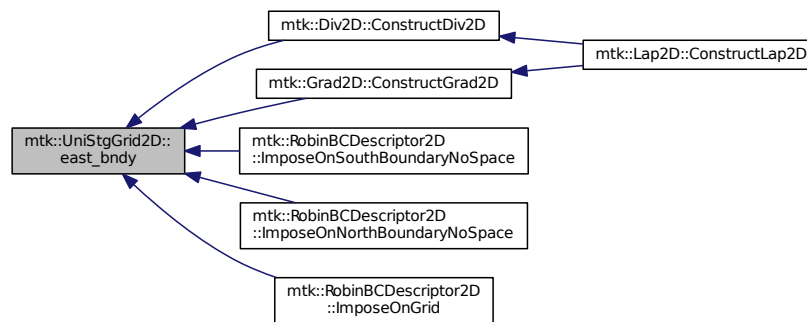
### 16.19.3.11 `mtk::Real mtk::UniStgGrid2D::east_bndy ( ) const`

## 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:



### 16.19.3.12 mtk::FieldNature mtk::UniStgGrid2D::nature ( ) const

## Returns

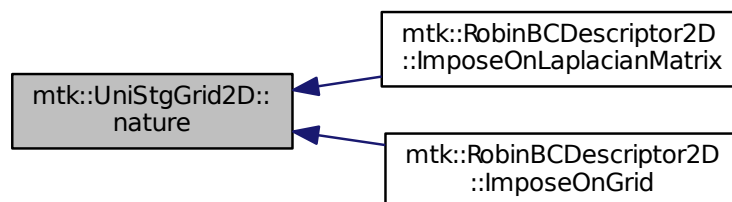
Value of an enumeration.

## See also

[mtk::FieldNature](#)

Definition at line 205 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

Here is the caller graph for this function:



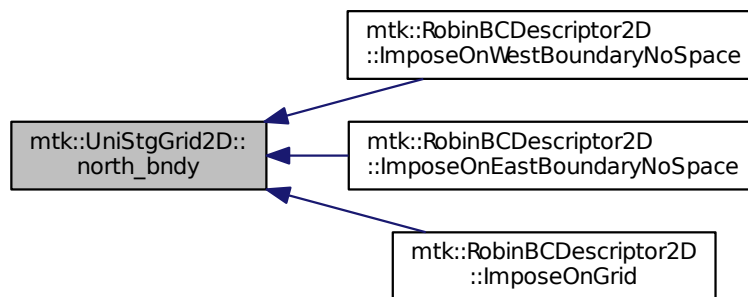
16.19.3.13 `mtk::Real mtk::UniStgGrid2D::north_bndy ( ) const`

#### 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:



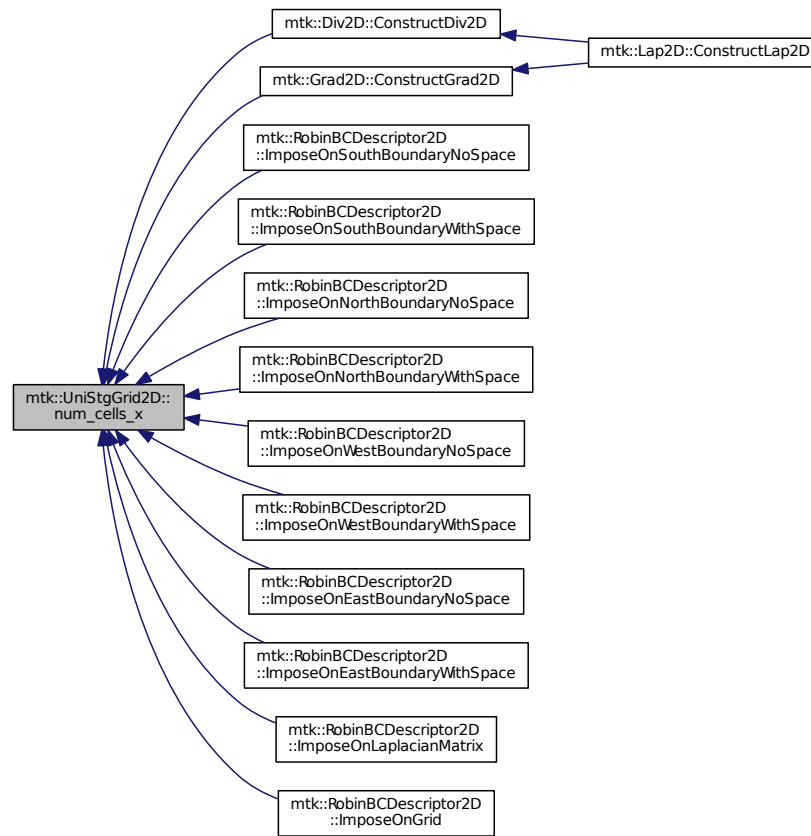
16.19.3.14 `int mtk::UniStgGrid2D::num_cells_x ( ) const`

#### 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:



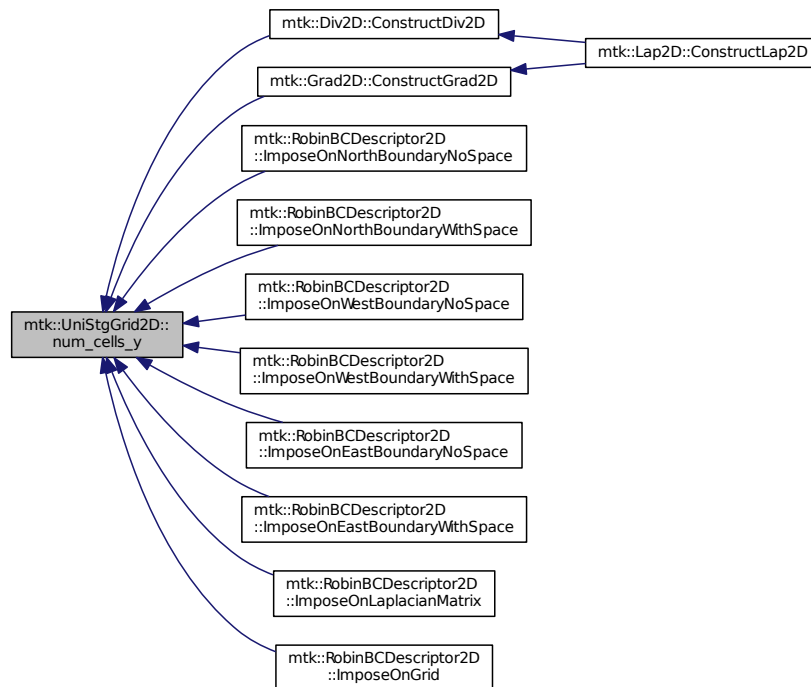
16.19.3.15 `int mtk::UniStgGrid2D::num_cells_y ( ) const`

## 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:



16.19.3.16 `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:

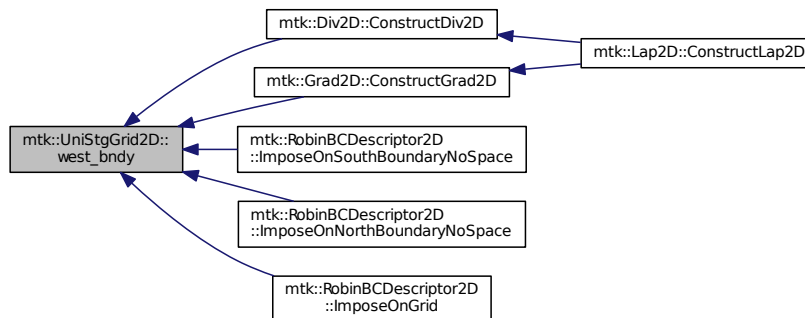
16.19.3.17 `mtk::Real mtk::UniStgGrid2D::west_bndy ( ) const`

## 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:

16.19.3.18 `bool mtk::UniStgGrid2D::WriteToFile ( std::string filename, std::string space_name_x, std::string space_name_y, std::string field_name ) const`

**Parameters**

in	<i>filename</i>	Name of the output file.
in	<i>space_name_x</i>	Name for the first column of the (spatial) data.
in	<i>space_name_y</i>	Name for the second column of the (spatial) data.
in	<i>field_name</i>	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 430 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

**16.19.4 Friends And Related Function Documentation**

16.19.4.1 `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](#).

**16.19.5 Member Data Documentation**

16.19.5.1 `Real mtk::UniStgGrid2D::delta_x_` `[private]`

Definition at line 298 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.2 `Real mtk::UniStgGrid2D::delta_y_` `[private]`

Definition at line 303 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.3 `std::vector<Real> mtk::UniStgGrid2D::discrete_domain_x_` `[private]`

Definition at line 289 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.4 `std::vector<Real> mtk::UniStgGrid2D::discrete_domain_y_` `[private]`

Definition at line 290 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).



16.19.5.5 `std::vector<Real> mtk::UniStgGrid2D::discrete_field_` [private]

Definition at line 291 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.6 `Real mtk::UniStgGrid2D::east_bndy_` [private]

Definition at line 296 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.7 `FieldNature mtk::UniStgGrid2D::nature_` [private]

Definition at line 293 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.8 `Real mtk::UniStgGrid2D::north_bndy_` [private]

Definition at line 301 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.9 `int mtk::UniStgGrid2D::num_cells_x_` [private]

Definition at line 297 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.10 `int mtk::UniStgGrid2D::num_cells_y_` [private]

Definition at line 302 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.11 `Real mtk::UniStgGrid2D::south_bndy_` [private]

Definition at line 300 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

16.19.5.12 `Real mtk::UniStgGrid2D::west_bndy_` [private]

Definition at line 295 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](#)



## Chapter 17

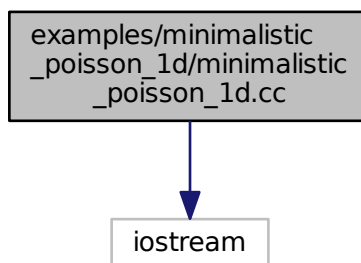
# File Documentation

### 17.1 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` ()

#### 17.1.1 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](#).

## 17.1.2 Function Documentation

### 17.1.2.1 int main ( )

Definition at line 164 of file [minimalistic\\_poisson\\_1d.cc](#).

## 17.2 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
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
00071 The copyright holders provide no reassurances that the source code provided does

```

```

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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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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::LaplD lap;
00128     if (!lap.ConstructLaplD()) {
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::RobinBCDescriptorID 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

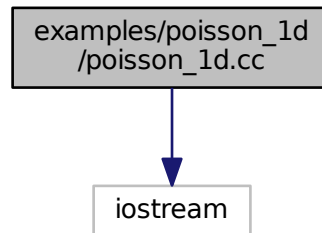
```

## 17.3 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` ()

#### 17.3.1 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 [poisson\\_1d.cc](#).

### 17.3.2 Function Documentation

#### 17.3.2.1 int main ( )

Definition at line 263 of file [poisson\\_1d.cc](#).

## 17.4 poisson\_1d.cc

```

00001
00043 /*
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00045 University. All rights reserved.
00046
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00048 are permitted provided that the following conditions are met:
00049
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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
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00058
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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
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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```

```

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00075 parties intellectual property rights.
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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
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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
00142     mtk::Real west_bndy_x{0.0};
00143     mtk::Real east_bndy_x{1.0};
00144     int num_cells_x{5};
00145
00146     mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00147
00148     mtk::Lap1D lap;
00149
00150     if (!lap.ConstructLap1D()) {
00151         std::cerr << "Mimetic Laplacian could not be built." << std::endl;
00152         return EXIT_FAILURE;
00153     }
00154 }
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     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_ld;
00182
00183     robin_bc_desc_ld.PushBackWestCoeff(Alpha);
00184     robin_bc_desc_ld.PushBackWestCoeff(Beta);
00185
00186     robin_bc_desc_ld.PushBackEastCoeff(Alpha);
00187     robin_bc_desc_ld.PushBackEastCoeff(Beta);
00188
00189     robin_bc_desc_ld.set_west_condition(Omega);
00190     robin_bc_desc_ld.set_east_condition(Epsilon);
00191
00192     if (!robin_bc_desc_ld.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_ld.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

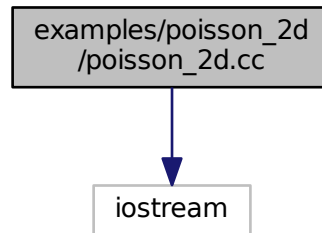
```

## 17.5 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` ()

#### 17.5.1 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 parameter.

We consider Robin's boundary conditions of the form:

$$\alpha p(a) - \beta p'(a) = \omega,$$

$$\alpha p(b) + \beta p'(b) = \varepsilon.$$

The analytical solution for this problem is given by

$$p(x) = \frac{\exp(\lambda x) - 1}{\exp(\lambda) - 1}.$$

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu  
 : Raul Vargas-Navarro - vargasna at rohan dot sdsu dot edu

Definition in file [poisson\\_2d.cc](#).

## 17.5.2 Function Documentation

### 17.5.2.1 int main ( )

Definition at line 108 of file [poisson\\_2d.cc](#).

## 17.6 poisson\_2d.cc

```
00001
00042 /*
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00044 University. All rights reserved.
00045
00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
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00049 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00050 and a copy of the modified files should be reported once modifications are
00051 completed, unless these modifications are made through the project's GitHub
00052 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00053 should be developed and included in any deliverable.
00054
00055 2. Redistributions of source code must be done through direct
00056 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00057
00058 3. Redistributions in binary form must reproduce the above copyright notice,
00059 this list of conditions and the following disclaimer in the documentation and/or
00060 other materials provided with the distribution.
00061
00062 4. Usage of the binary form on proprietary applications shall require explicit
```

```

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00081 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00082 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00083 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00084 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00085 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00086 */
00087
00088 #if __cplusplus == 201103L
00089
00090 #include <iostream>
00091 #include <fstream>
00092 #include <cmath>
00093
00094 #include <vector>
00095
00096 #include "mtk.h"
00097
00098 int main () {
00099
00100     std::cout << "Example: Poisson Equation on a 2D Uniform Staggered Grid ";
00101     std::cout << "with Robin BCs." << std::endl;
00102 }
00103
00104 #else
00105 #include <iostream>
00106 using std::cout;
00107 using std::endl;
00108 int main () {
00109     cout << "This code HAS to be compiled with support for C++11." << endl;
00110     cout << "Exiting..." << endl;
00111     return EXIT_SUCCESS;
00112 }
00113 #endif

```

## 17.7 include/mtk.h File Reference

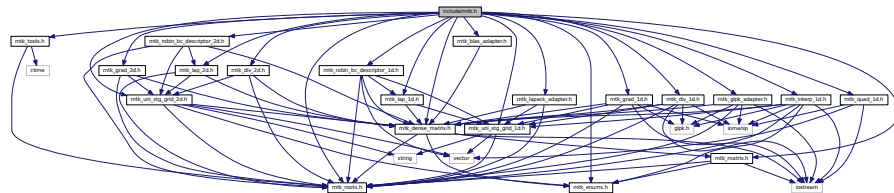
Includes the entire API.

```

#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_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_lap_2d.h"
#include "mtk_robin_bc_descriptor_2d.h"

```

Include dependency graph for mtk.h:



### 17.7.1 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](#).

## 17.8 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
00039 5. Neither the name of the copyright holder nor the names of its contributors
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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 */
00379 #ifndef MTK_INCLUDE_MTK_H_
00380 #define MTK_INCLUDE_MTK_H_
00381
00389 #include "mtk_roots.h"
00390
00398 #include "mtk_enums.h"
00399
00407 #include "mtk_tools.h"
00408
00416 #include "mtk_matrix.h"
00417 #include "mtk_dense_matrix.h"
00418
00426 #include "mtk_blas_adapter.h"
00427 #include "mtk_lapack_adapter.h"
00428 #include "mtk_glpk_adapter.h"
00429
00437 #include "mtk_uni_stg_grid_1d.h"
00438 #include "mtk_uni_stg_grid_2d.h"
00439
00447 #include "mtk_grad_1d.h"
00448 #include "mtk_div_1d.h"
00449 #include "mtk_lap_1d.h"
00450 #include "mtk_robin_bc_descriptor_1d.h"
00451 #include "mtk_quad_1d.h"
00452 #include "mtk_interp_1d.h"
00453
00454 #include "mtk_grad_2d.h"
00455 #include "mtk_div_2d.h"
00456 #include "mtk_lap_2d.h"
00457 #include "mtk_robin_bc_descriptor_2d.h"
00458
00459 #endif // End of: MTK_INCLUDE_MTK_H_

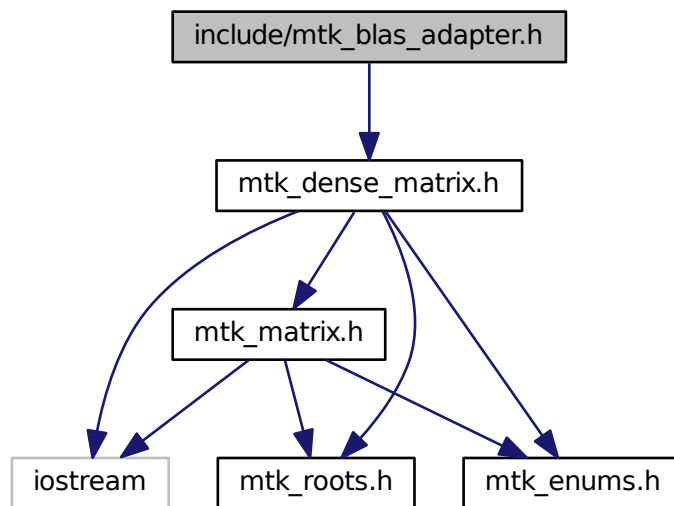
```

## 17.9 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.

### 17.9.1 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](#).

### 17.10 mtk\_blas\_adapter.h

```
00001
00024 /*
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00026 University. All rights reserved.
00027
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00029 are permitted provided that the following conditions are met:
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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
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00041 this list of conditions and the following disclaimer in the documentation and/or
00042 other materials provided with the distribution.
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00044 4. Usage of the binary form on proprietary applications shall require explicit
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00046 be given to the copyright holders.
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00049 may be used to endorse or promote products derived from this software without
00050 specific prior written permission.
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00052 The copyright holders provide no reassurances that the source code provided does
00053 not infringe any patent, copyright, or any other intellectual property rights of
00054 third parties. The copyright holders disclaim any liability to any recipient for
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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
00077 class BLASAdapter {
00078 public:
00079     static Real RealNRM2(Real *in, int &in_length);
00080
00081     static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00082
00083     static Real RelNorm2Error(Real *computed, Real *known, int length);
00084
00085     static void RealDenseMV(Real &alpha,
00086                             DenseMatrix &aa,
00087                             Real *xx,
00088                             Real &beta,
00089                             Real *yy);
00090
00091     static DenseMatrix RealDenseMM(DenseMatrix &aa,
00092                                    DenseMatrix &bb);
00093
00094     static DenseMatrix RealDenseSM(Real alpha,
00095                                    DenseMatrix &aa);
00096 };
00097
00098 #endif // End of: MTK_INCLUDE_BLAS_ADAPTER_H_

```

## 17.11 include/mtk\_dense\_matrix.h File Reference

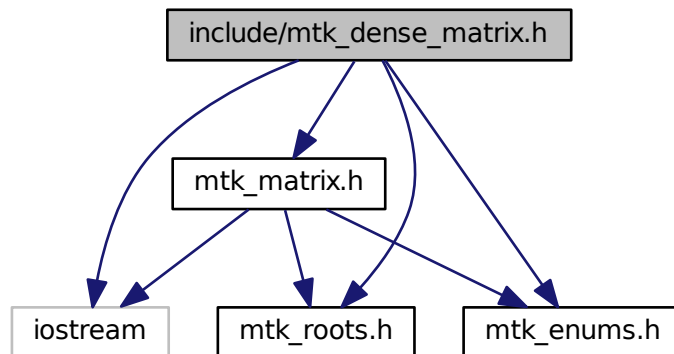
Defines a common dense matrix, using a 1D array.

```

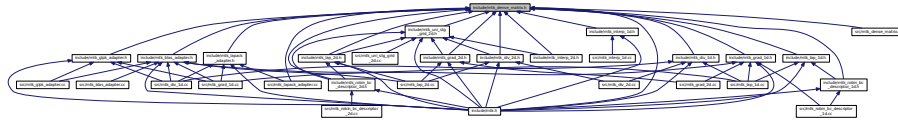
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_matrix.h"

```

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.*

### 17.11.1 Detailed Description

For developing purposes, it is better to have a not-so-intricated 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](#).

## 17.12 mtk\_dense\_matrix.h

```
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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
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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_

```

## 17.13 include/mtk\_div\_1d.h File Reference

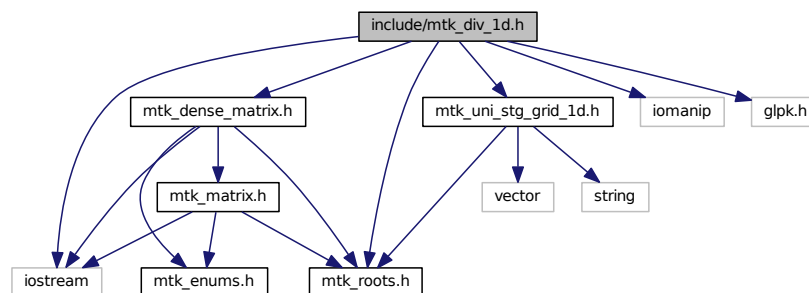
Includes the definition of the class Div1D.

```

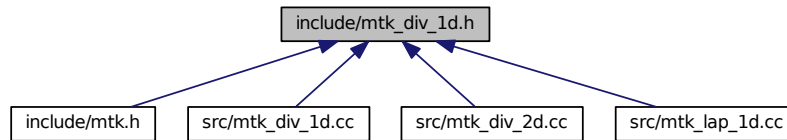
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.13.1 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](#).

## 17.14 mtk\_div\_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.
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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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00030

```

```

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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_DIV1D_H_
00058 #define MTK_INCLUDE_DIV1D_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:
00083     friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00084
00085     Div1D();
00086
00087     Div1D(const Div1D &div);
00088
00089     ~Div1D();
00090
00091     bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00092                        Real mimetic_threshold = kDefaultMimeticThreshold);
00093
00094     int num_bndy_coeffs() const;
00095
00096     Real *coeffs_interior() const;
00097
00098     Real *weights_crs(void) const;
00099
00100     Real *weights_cbs(void) const;
00101
00102     DenseMatrix mim_bndy() const;
00103
00104     DenseMatrix ReturnAsDenseMatrix(const
00105     UniStgGrid1D &grid) const;
00106
00107 private:
00108     bool ComputeStencilInteriorGrid(void);
00109
00110     bool ComputeRationalBasisNullSpace(void);
00111
00112     bool ComputePreliminaryApproximations(void);
00113
00114     bool ComputeWeights(void);
00115
00116     bool ComputeStencilBoundaryGrid(void);
00117
00118     bool AssembleOperator(void);
00119
00120     int order_accuracy_;
00121     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_

```

## 17.15 include/mtk\_div\_2d.h File Reference

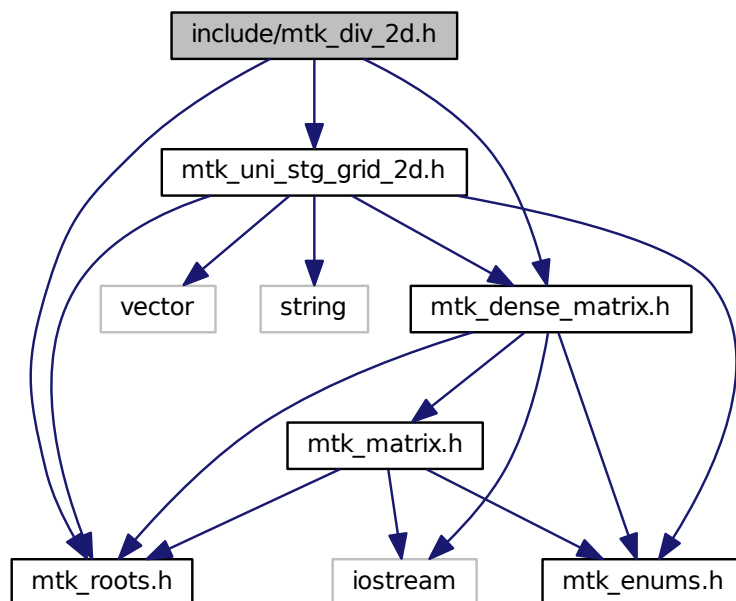
Includes the definition of the class Div2D.

```

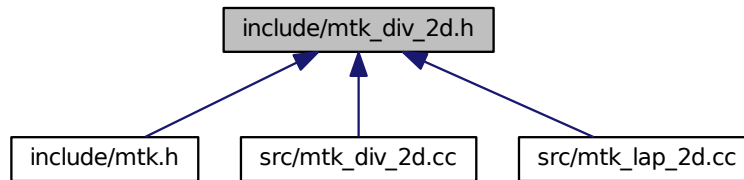
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"

```

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.*

### 17.15.1 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](#).

## 17.16 mtk\_div\_2d.h

```

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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

```



```

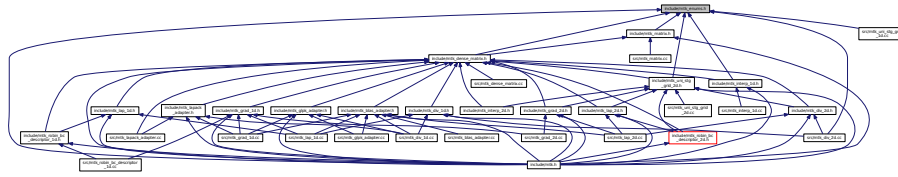
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00047 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00048 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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00050 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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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
00066 class Div2D {
00067 public:
00068     Div2D();
00069
00070     Div2D(const Div2D &div);
00071
00072     ~Div2D();
00073
00074     bool ConstructDiv2D(const UniStgGrid2D &grid,
00075                        int order_accuracy = kDefaultOrderAccuracy,
00076                        Real mimetic_threshold = kDefaultMimeticThreshold);
00077
00078     DenseMatrix ReturnAsDenseMatrix() const;
00079
00080 private:
00081     DenseMatrix divergence_;
00082
00083     int order_accuracy_;
00084
00085     Real mimetic_threshold_;
00086 };
00087
00088 #endif // End of: MTK_INCLUDE_MTK_DIV_2D_H_

```

## 17.17 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.*

### 17.17.1 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](#).

## 17.18 mtk\_enums.h

```

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00014 University. All rights reserved.
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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

```

```

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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_

```

## 17.19 include/mtk\_glpk\_adapter.h File Reference

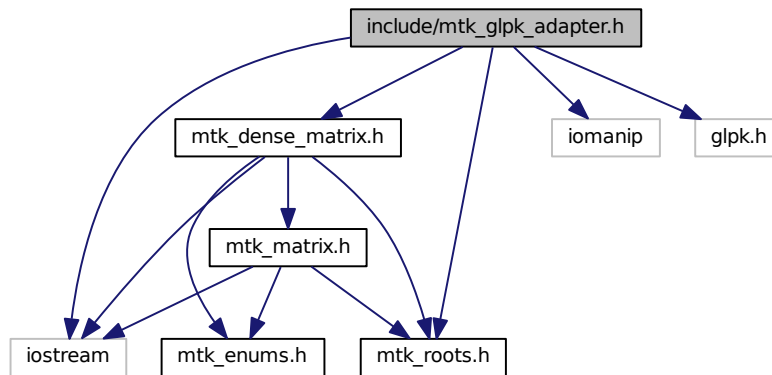
Adapter class for the GLPK API.

```

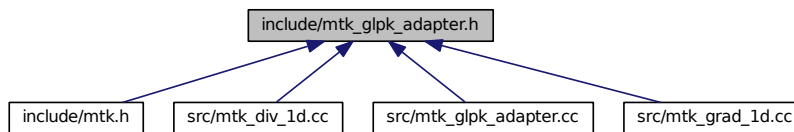
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"

```

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.*

### 17.19.1 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](#).

## 17.20 mtk\_glpk\_adapter.h

```

00001
00019 /*
00020 Copyright (C) 2015, Computational Science Research Center, San Diego State
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:
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
00034
00035 3. Redistributions in binary form must reproduce the above copyright notice,
00036 this list of conditions and the following disclaimer in the documentation and/or
00037 other materials provided with the distribution.
00038
00039 4. Usage of the binary form on proprietary applications shall require explicit
00040 prior written permission from the the copyright holders, and due credit should
00041 be given to the copyright holders.
00042
00043 5. Neither the name of the copyright holder nor the names of its contributors
00044 may be used to endorse or promote products derived from this software without
00045 specific prior written permission.
00046
00047 The copyright holders provide no reassurances that the source code provided does
00048 not infringe any patent, copyright, or any other intellectual property rights of
00049 third parties. The copyright holders disclaim any liability to any recipient for
00050 claims brought against recipient by any third party for infringement of that
00051 parties intellectual property rights.
00052
00053 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00054 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00055 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00056 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00057 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00058 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00059 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
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(
00124         mtk::Real *A,
00125         int nrows,
00126         int ncols,
00127         int kk,
00128         mtk::Real *hh,
00129         mtk::Real *qq,
00130         int robjective,
00131         mtk::Real mimetic_tol,
00132         int copy);
00133 }
00134 #endif // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_

```

## 17.21 include/mtk\_grad\_1d.h File Reference

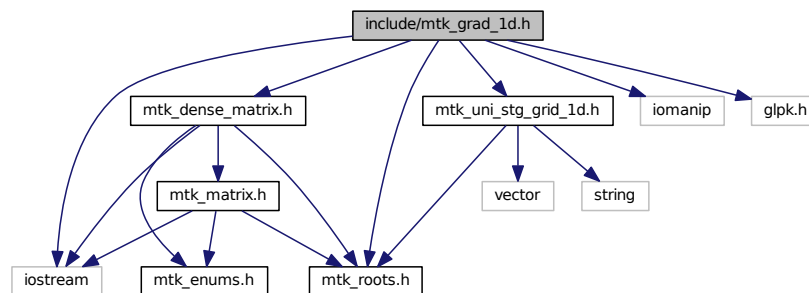
Includes the definition of the class Grad1D.

```

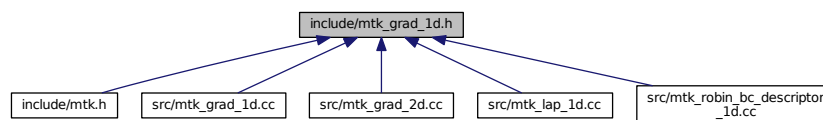
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.21.1 Detailed Description

This class implements a 1D 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\\_1d.h](#).

## 17.22 mtk\_grad\_1d.h

```

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
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
00031 4. Usage of the binary form on proprietary applications shall require explicit
00032 prior written permission from the the copyright holders, and due credit should
00033 be given to the copyright holders.
00034
00035 5. Neither the name of the copyright holder nor the names of its contributors
00036 may be used to endorse or promote products derived from this software without
00037 specific prior written permission.
00038
00039 The copyright holders provide no reassurances that the source code provided does
00040 not infringe any patent, copyright, or any other intellectual property rights of
00041 third parties. The copyright holders disclaim any liability to any recipient for
00042 claims brought against recipient by any third party for infringement of that
00043 parties intellectual property rights.
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00047 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00048 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00049 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00050 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00051 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
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:
00083     friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00084
00085     Grad1D();
00086
00087     Grad1D(const Grad1D &grad);
00088
00089     ~Grad1D();
00090
00091     bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00092                         Real mimetic_threshold = kDefaultMimeticThreshold);
00093
00094     int num_bndy_coeffs() const;
00095
00096     Real *coeffs_interior() const;
00097
00098     Real *weights_crs(void) const;
00099
00100     Real *weights_cbs(void) const;
00101
00102     DenseMatrix mim_bndy() const;
00103
00104     DenseMatrix ReturnAsDenseMatrix(Real west,
00105                                     Real east, int num_cells_x) const;
00106
00107     DenseMatrix ReturnAsDenseMatrix(const
00108                                     UniStgGrid1D &grid) const;
00109
00110     DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
00111     const;
00112
00113 private:
00114     bool ComputeStencilInteriorGrid(void);
00115
00116     bool ComputeRationalBasisNullSpace(void);
00117
00118     bool ComputePreliminaryApproximations(void);
00119
00120     bool ComputeWeights(void);
00121
00122     bool ComputeStencilBoundaryGrid(void);
00123
00124     bool AssembleOperator(void);
00125
00126     int order_accuracy_;
00127     int dim_null_;
00128     int num_bndy_approxs_;
00129     int num_bndy_coeffs_;
00130     int gradient_length_;
00131     int minrow_;
00132     int row_;
00133
00134     DenseMatrix rat_basis_null_space_;
00135
00136     Real *coeffs_interior_;
00137     Real *prem_apps_;
00138     Real *weights_crs_;
00139     Real *weights_cbs_;
00140     Real *mim_bndy_;
00141     Real *gradient_;
00142
00143     Real mimetic_threshold_;
00144 };
00145
00146 #endif // End of: MTK_INCLUDE_GRAD_1D_H_

```

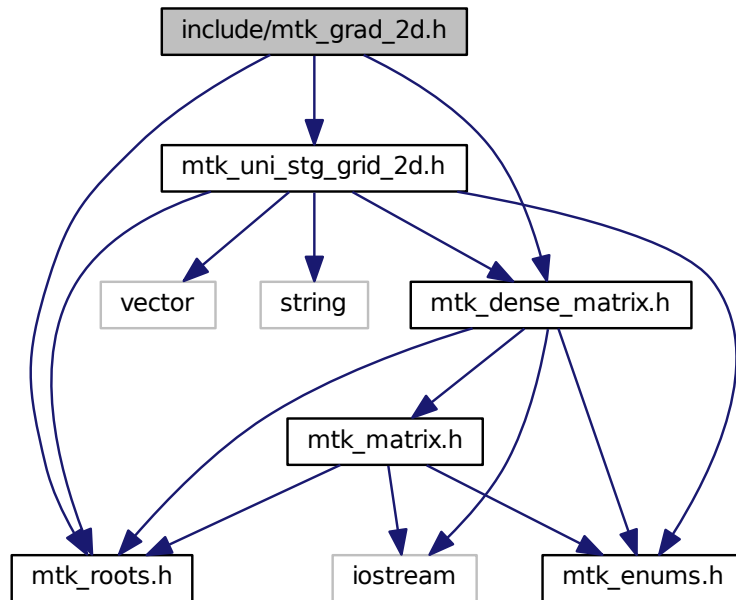


## 17.23 include/mtk\_grad\_2d.h File Reference

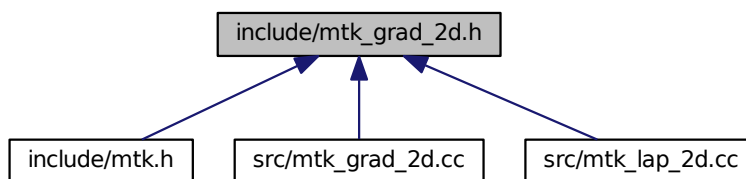
Includes the definition of the class Grad2D.

```
#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.*

### 17.23.1 Detailed Description

This class implements a 2D 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\\_2d.h](#).

## 17.24 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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00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
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00031 4. Usage of the binary form on proprietary applications shall require explicit
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00047 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00048 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00049 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00050 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00051 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
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
00066 class Grad2D {
00067 public:
00068     Grad2D();
00069
00070     Grad2D(const Grad2D &grad);
00071
00072     ~Grad2D();
00073
00074     bool ConstructGrad2D(const UniStgGrid2D &grid,
00075                         int order_accuracy = kDefaultOrderAccuracy,
00076                         Real mimetic_threshold = kDefaultMimeticThreshold);
00077
00078     DenseMatrix ReturnAsDenseMatrix() const;
00079
00080 private:
00081     DenseMatrix gradient_;
00082     int order_accuracy_;
00083     Real mimetic_threshold_;
00084 };
00085
00086 #endif // End of: MTK_INCLUDE_MTK_GRAD_2D_H_

```

## 17.25 include/mtk\_interp\_1d.h File Reference

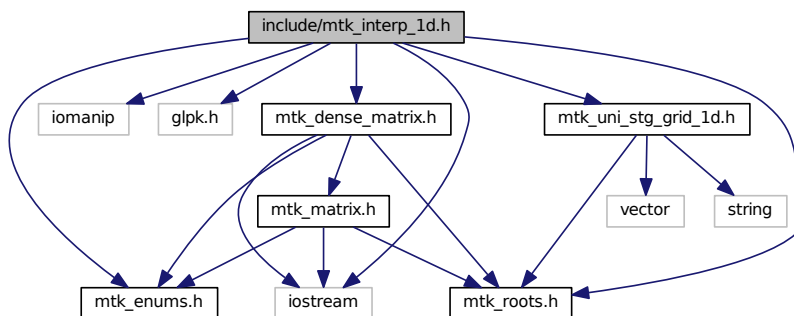
Includes the definition of the class Interp1D.

```

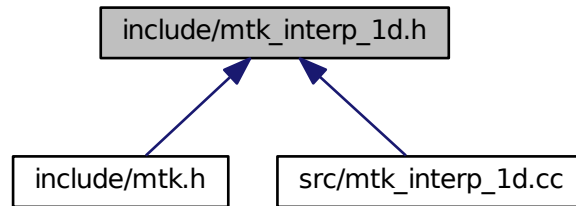
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.25.1 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`.

## 17.26 mtk\_interp\_1d.h

```

00001
00012 /*
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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.
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00042 third parties. The copyright holders disclaim any liability to any recipient for
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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_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_

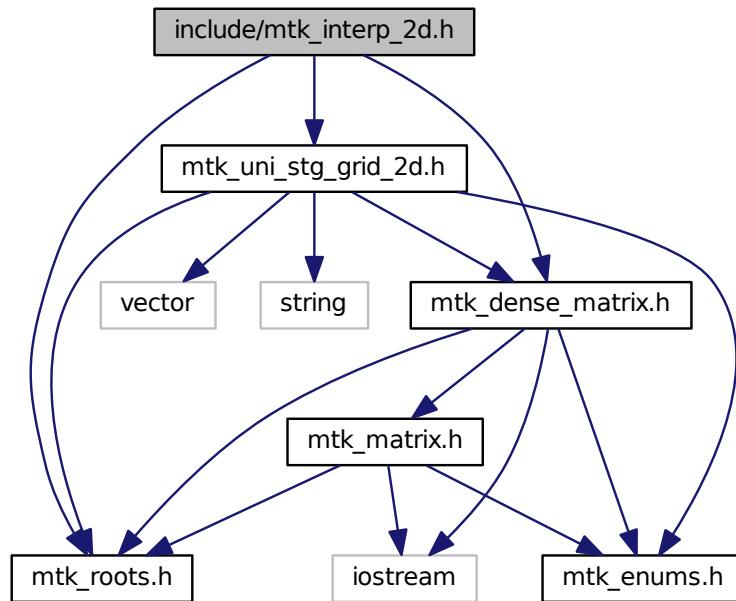
```

## 17.27 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.*

#### 17.27.1 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](#).

## 17.28 mtk\_interp\_2d.h

```

00001
00012 /*
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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.
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00040 The copyright holders provide no reassurances that the source code provided does
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00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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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_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 =
00099                                     kDefaultMimeticThreshold);
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_

```

## 17.29 include/mtk\_lap\_1d.h File Reference

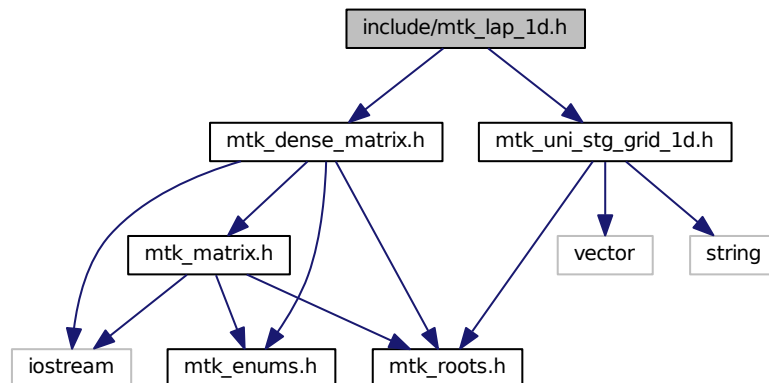
Includes the definition of the class Lap1D.

```

#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

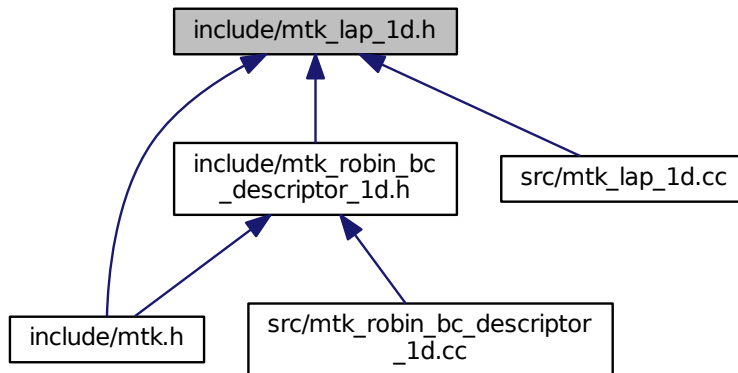
```

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.*

### 17.29.1 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`.

## 17.30 mtk\_lap\_1d.h

```

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```

```

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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
00066 class Lap1D {
00067 public:
00068     friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00069
00070     Lap1D();
00071
00072     Lap1D(const Lap1D &lap);
00073
00074     ~Lap1D();
00075
00076     int order_accuracy() const;
00077
00078     Real mimetic_threshold() const;
00079
00080     Real delta() const;
00081
00082     bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00083                        Real mimetic_threshold = kDefaultMimeticThreshold);
00084
00085     DenseMatrix ReturnAsDenseMatrix(const
00086     UniStgGrid1D &grid) const;
00087
00088     const mtk::Real* data(const UniStgGrid1D &grid) const;
00089
00090 private:
00091     int order_accuracy_;
00092     int laplacian_length_;
00093
00094     Real *laplacian_;
00095
00096     mutable Real delta_;
00097
00098     Real mimetic_threshold_;

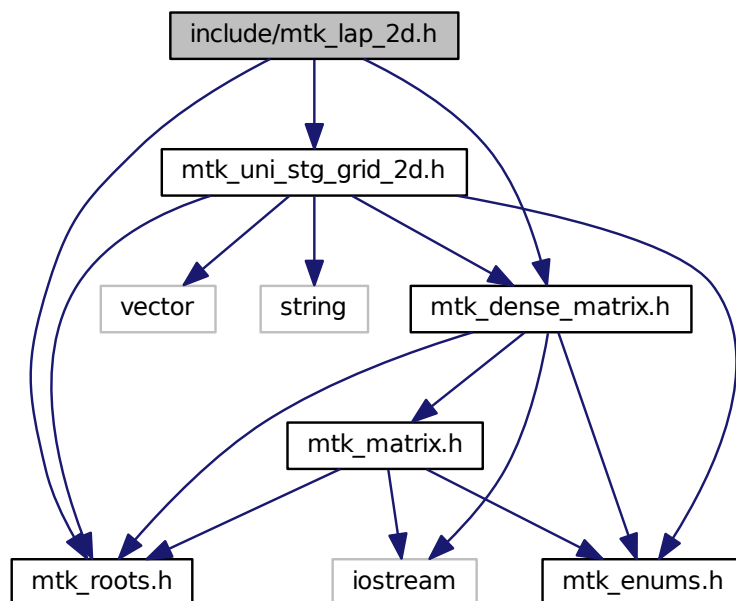
```

```
00146 };  
00147 }  
00148 #endif // End of: MTK_INCLUDE_LAP_1D_H_
```

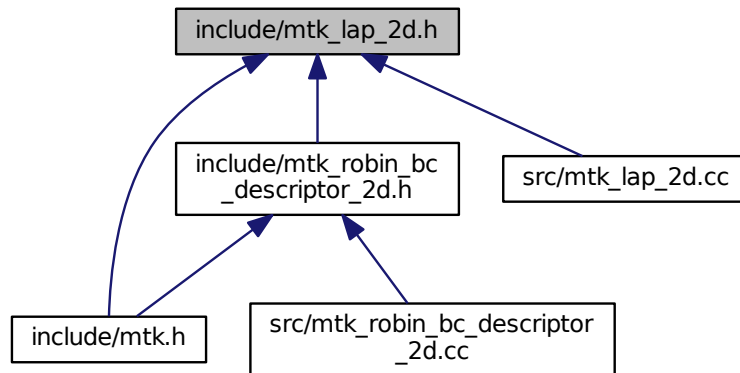
## 17.31 include/mtk\_lap\_2d.h File Reference

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.*

### 17.31.1 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](#).

## 17.32 mtk\_lap\_2d.h

```

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```

```

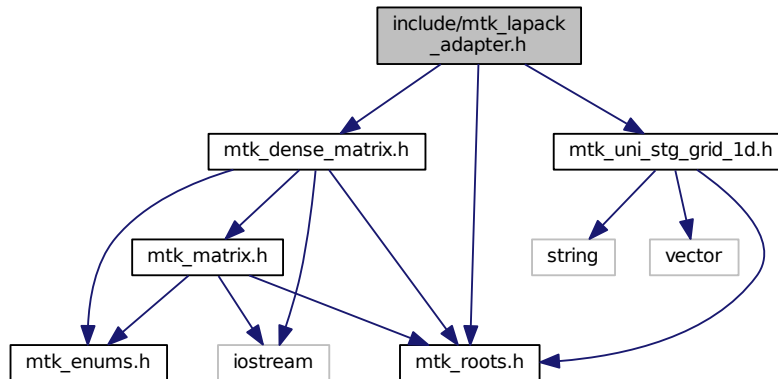
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
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00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_LAP_2D_H_
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:
00078     Lap2D();
00079
00080     Lap2D(const Lap2D &lap);
00081
00082     ~Lap2D();
00083
00084     bool ConstructLap2D(const UniStgGrid2D &grid,
00085                        int order_accuracy = kDefaultOrderAccuracy,
00086                        Real mimetic_threshold = kDefaultMimeticThreshold);
00087
00088     DenseMatrix ReturnAsDenseMatrix() const;
00089
00090     Real *data() const;
00091
00092 private:
00093     DenseMatrix laplacian_;
00094
00095     int order_accuracy_;
00096
00097     Real mimetic_threshold_;
00098 };
00099
00100 #endif // End of: MTK_INCLUDE_MTK_LAP_2D_H_

```

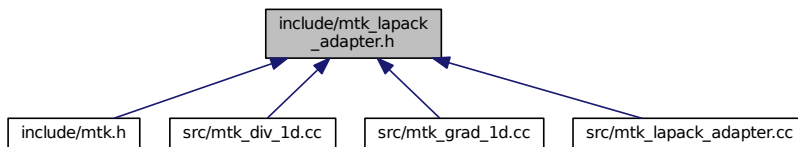
## 17.33 include/mtk\_lapack\_adapter.h File Reference

Adapter class for the LAPACK API.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
Include 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.*

### 17.33.1 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](#).

## 17.34 mtk\_lapack\_adapter.h

```

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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_ld.h"
00071
00072 namespace mtk {
00073
00092 class LAPACKAdapter {
00093 public:
00104     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00105                                mtk::Real *rhs);
00106
00117     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00118                                mtk::DenseMatrix &rr);
00119
00130     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00131                                mtk::UniStgGridLD &rhs);
00132
00144     static int SolveRectangularDenseSystem(const
00145                                             mtk::DenseMatrix &aa,
00146                                             mtk::Real *ob_,
00147                                             int ob_ld_);
00148
00159     static mtk::DenseMatrix QRFactorDenseMatrix(
00160         DenseMatrix &matrix);
00161 };
00162 #endif // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_

```

## 17.35 include/mtk\_matrix.h File Reference

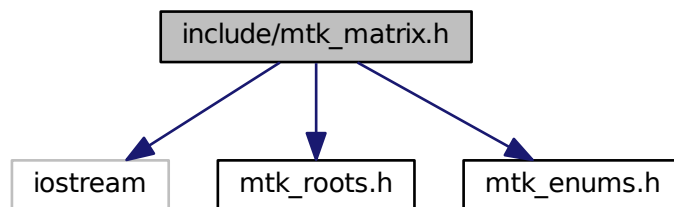
Definition of the representation of a matrix in the MTK.

```

#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"

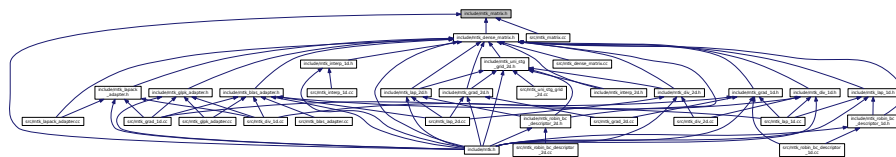
```

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.*

### 17.35.1 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](#).

## 17.36 mtk\_matrix.h

```

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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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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 #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:
00077     Matrix();
00078
00079     Matrix(const Matrix &in);
00080
00081     ~Matrix() noexcept;
00082
00083     MatrixStorage storage() const noexcept;
00084
00085     MatrixOrdering ordering() const noexcept;
00086
00087     int num_rows() const noexcept;
00088
00089     int num_cols() const noexcept;
00090
00091     int num_values() const noexcept;
00092
00093     int ld() const noexcept;
00094
00095     int num_zero() const noexcept;
00096
00097     int num_non_zero() const noexcept;
00098
00099     int num_null() const noexcept;
00100
00101     int num_non_null() const noexcept;
00102
00103     int kl() const noexcept;
00104
00105     int ku() const noexcept;
00106
00107     int bandwidth() const noexcept;
00108
00109     Real abs_density() const noexcept;
00110
00111     Real rel_density() const noexcept;
00112
00113     Real abs_sparsity() const noexcept;
00114
00115     Real rel_sparsity() const noexcept;
00116
00117     void set_storage(const MatrixStorage &tt) noexcept;
00118
00119     void set_ordering(const MatrixOrdering &oo) noexcept;
00120
00121     void set_num_rows(const int &num_rows) noexcept;
00122
00123     void set_num_cols(const int &num_cols) noexcept;
00124
00125     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_

```

## 17.37 include/mtk\_quad\_1d.h File Reference

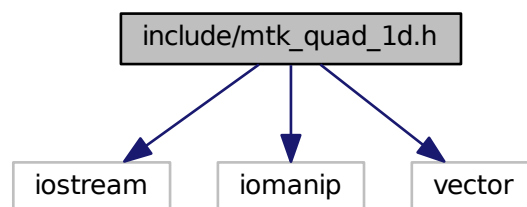
Includes the definition of the class Quad1D.

```

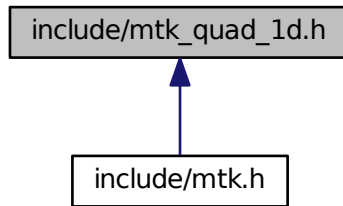
#include <iostream>
#include <iomanip>
#include <vector>

```

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.*

### 17.37.1 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](#).

## 17.38 mtk\_quad\_1d.h

```
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00023 and a copy of the modified files should be reported once modifications are
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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:
00083     friend std::ostream& operator <<(std::ostream& stream, Quad1D &in);
00084
00085     Quad1D();
00086
00087     Quad1D(const Quad1D &quad);
00088
00089     ~Quad1D();
00090
00091     int degree_approximation() const;
00092
00093     Real *weights() const;
00094
00095     Real Integrate(Real (*Integrand)(Real xx), UniStgGrid1D grid) const;
00096
00097 private:
00098     int degree_approximation_;
00099
00100     std::vector<Real> weights_;
00101 };
00102
00103 #endif // End of: MTK_INCLUDE_QUAD_1D_H_

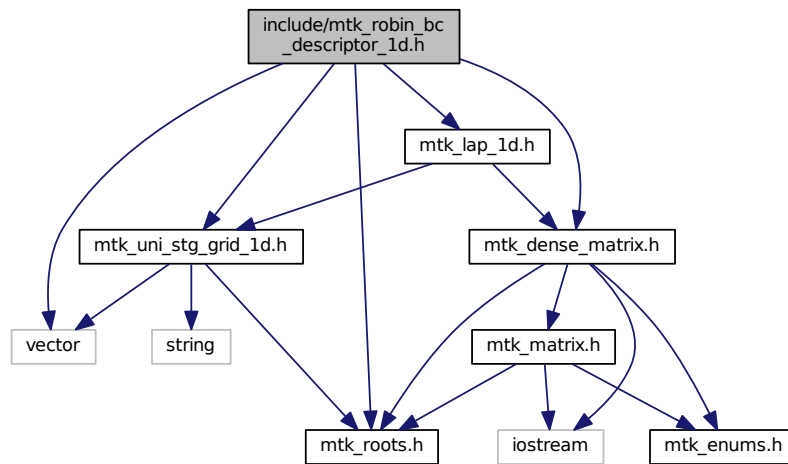
```

## 17.39 include/mtk\_robin\_bc\_descriptor\_1d.h File Reference

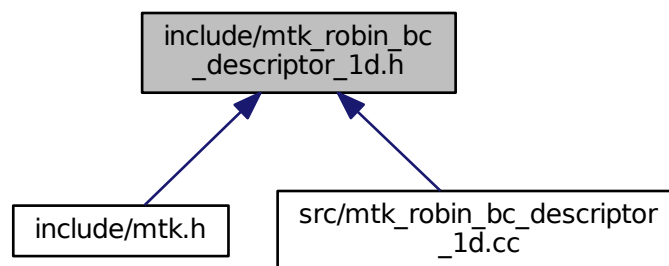
Impose Robin boundary conditions on the operators and on the grids.

```
#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.*

### 17.39.1 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](#).

## 17.40 mtk\_robin\_bc\_descriptor\_1d.h

```
00001
00043 /*
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00046
```

```

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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
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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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_ld.h"
00094 #include "mtk_lap_ld.h"
00095
00096 #ifndef MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_LD_H_
00097 #define MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_LD_H_
00098
00099 namespace mtk {
00100     00111 typedef Real (*CoefficientFunction0D)(const Real &tt);
00112
00155 class RobinBCDescriptor1D {
00156 public:
00157     RobinBCDescriptor1D();
00158
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 =

```



```

00231     mtk::kZero) const;
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_

```

## 17.41 include/mtk\_robin\_bc\_descriptor\_2d.h File Reference

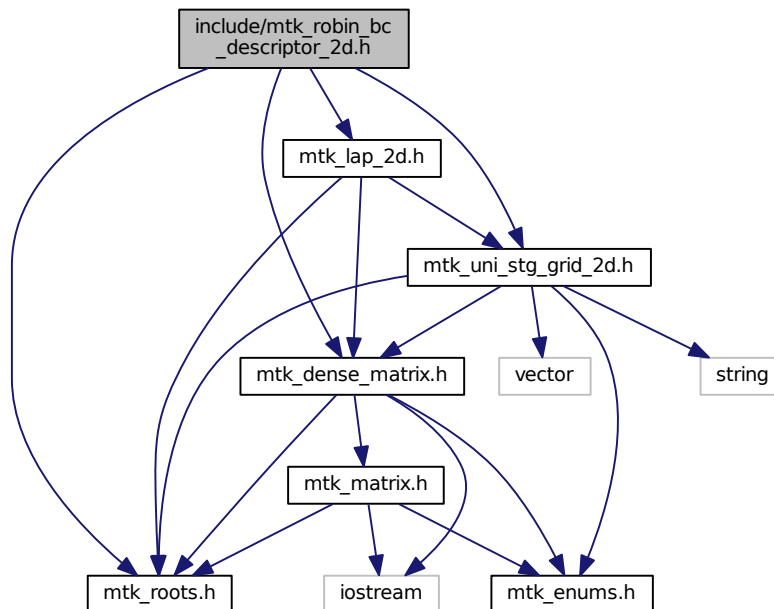
Impose Robin boundary conditions on the operators and on the grids.

```

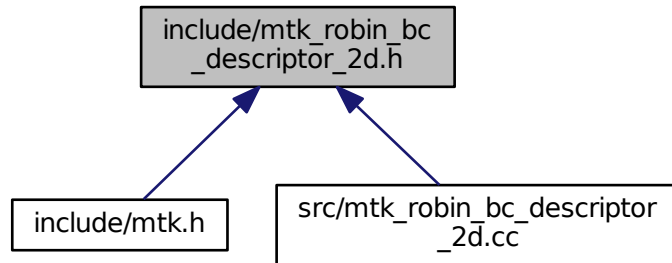
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_lap_2d.h"
#include "mtk_uni_stg_grid_2d.h"

```

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.*

### 17.41.1 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](#).

## 17.42 mtk\_robin\_bc\_descriptor\_2d.h

```

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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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00075 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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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
00099 class RobinBCDescriptor2D {

```

```

00133 public:
00134     RobinBCDescriptor2D();
00135
00136     RobinBCDescriptor2D(const RobinBCDescriptor2D &desc);
00137
00138     ~RobinBCDescriptor2D() noexcept;
00139
00140     int highest_order_diff_west() const noexcept;
00141
00142     int highest_order_diff_east() const noexcept;
00143
00144     int highest_order_diff_south() const noexcept;
00145
00146     int highest_order_diff_north() const noexcept;
00147
00148     void PushBackWestCoeff(CoefficientFunction1D cw);
00149
00150     void PushBackEastCoeff(CoefficientFunction1D ce);
00151
00152     void PushBackSouthCoeff(CoefficientFunction1D cs);
00153
00154     void PushBackNorthCoeff(CoefficientFunction1D cn);
00155
00156     void set_west_condition(Real (*west_condition)(const
00157 Real &yy,
00158                                     const Real &tt)) noexcept;
00159
00160     void set_east_condition(Real (*east_condition)(const
00161 Real &yy,
00162                                     const Real &tt)) noexcept;
00163
00164     void set_south_condition(Real (*south_condition)(const
00165 Real &xx,
00166                                     const Real &tt)) noexcept;
00167
00168     void set_north_condition(Real (*north_condition)(const
00169 Real &xx,
00170                                     const Real &tt)) noexcept;
00171
00172     bool ImposeOnLaplacianMatrix(const Lap2D &lap,
00173                                 const UniStgGrid2D &grid,
00174                                 DenseMatrix &matrix,
00175                                 const Real &time = kZero) const;
00176     void ImposeOnGrid(UniStgGrid2D &grid, const Real &time =
00177 kZero) const;
00178
00179 private:
00180     bool ImposeOnSouthBoundaryNoSpace(const Lap2D &lap,
00181                                     const UniStgGrid2D &grid,
00182                                     DenseMatrix &matrix,
00183                                     const Real &time = kZero) const;
00184     bool ImposeOnNorthBoundaryNoSpace(const Lap2D &lap,
00185                                     const UniStgGrid2D &grid,
00186                                     DenseMatrix &matrix,
00187                                     const Real &time = kZero) const;
00188     bool ImposeOnWestBoundaryNoSpace(const Lap2D &lap,
00189                                     const UniStgGrid2D &grid,
00190                                     DenseMatrix &matrix,
00191                                     const Real &time = kZero) const;
00192     bool ImposeOnEastBoundaryNoSpace(const Lap2D &lap,
00193                                     const UniStgGrid2D &grid,
00194                                     DenseMatrix &matrix,
00195                                     const Real &time = kZero) const;
00196     bool ImposeOnSouthBoundaryWithSpace(const Lap2D &lap,
00197                                     const UniStgGrid2D &grid,
00198                                     DenseMatrix &matrix,
00199                                     const Real &time = kZero) const;
00200     bool ImposeOnNorthBoundaryWithSpace(const Lap2D &lap,
00201                                     const UniStgGrid2D &grid,
00202                                     DenseMatrix &matrix,
00203                                     const Real &time = kZero) const;
00204     bool ImposeOnWestBoundaryWithSpace(const Lap2D &lap,
00205                                     const UniStgGrid2D &grid,
00206                                     DenseMatrix &matrix,
00207                                     const Real &time = kZero) const;
00208     bool ImposeOnEastBoundaryWithSpace(const Lap2D &lap,
00209                                     const UniStgGrid2D &grid,
00210                                     DenseMatrix &matrix,
00211                                     const Real &time = kZero) const;
00212
00213     int highest_order_diff_west_;

```

```

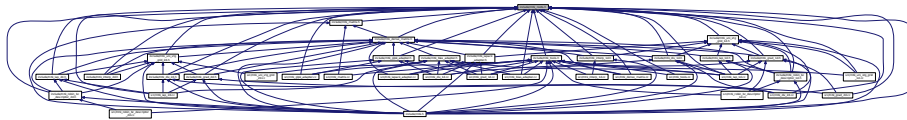
00362 int highest_order_diff_east_;
00363 int highest_order_diff_south_;
00364 int highest_order_diff_north_;
00365
00366 std::vector<CoefficientFunction1D> west_coefficients_;
00367 std::vector<CoefficientFunction1D> east_coefficients_;
00368 std::vector<CoefficientFunction1D> south_coefficients_;
00369 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_

```

## 17.43 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.*

### 17.43.1 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`.

## 17.44 mtk\_roots.h

```

00001
00017 /*
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00019 University. All rights reserved.
00020
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00022 are permitted provided that the following conditions are met:
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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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```

```

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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_

```

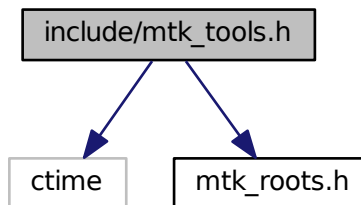
## 17.45 include/mtk\_tools.h File Reference

Tool manager class.

```
#include <ctime>
```

```
#include "mtk_roots.h"
```

Include dependency graph for mtk\_tools.h:







```

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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_

```

## 17.47 include/mtk\_uni\_stg\_grid\_1d.h File Reference

Definition of an 1D uniform staggered grid.

```

#include <vector>
#include <string>
#include "mtk_roots.h"

```



## 17.48 mtk\_uni\_stg\_grid\_1d.h

```

00001
00012 /*
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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
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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_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
00174     void BindVectorField(Real (*VectorField)(Real xx));
00175
00187     bool WriteToFile(std::string filename,
00188                     std::string space_name,
00189                     std::string field_name) const;
00190
00191 private:
00192     FieldNature nature_;
00193
00194     std::vector<Real> discrete_domain_x_;
00195     std::vector<Real> discrete_field_;
00196
00197     Real west_bndy_x_;
00198     Real east_bndy_x_;
00199     Real num_cells_x_;
00200     Real delta_x_;
00201 };
00202 }
00203 #endif // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_

```

## 17.49 include/mtk\_uni\_stg\_grid\_2d.h File Reference

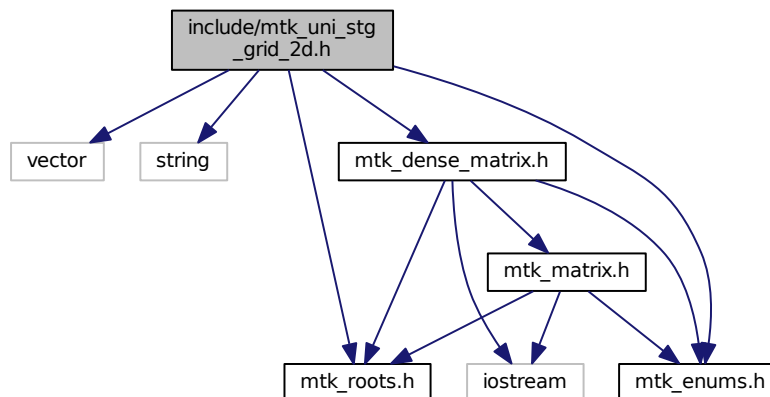
Definition of an 2D uniform staggered grid.

```

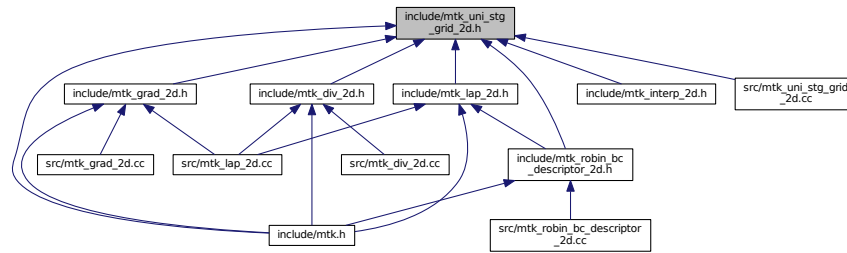
#include <vector>
#include <string>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"

```

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.*

### 17.49.1 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`.

## 17.50 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 =
00114 mtk::SCALAR);
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  void BindScalarField(Real (*ScalarField)(const Real &xx, const
Real &yy));
00221
00236  void BindVectorField(Real (*VectorFieldPComponent)(const
Real &xx,
00237                                     const Real &yy),
00238                      Real (*VectorFieldQComponent)(const Real &xx,
00239                                     const Real &yy));
00240
00253  bool WriteToFile(std::string filename,
00254                  std::string space_name_x,
00255                  std::string space_name_y,
00256                  std::string field_name) const;
00257
00258 private:
00271  void BindVectorFieldPComponent(
00272      Real (*VectorFieldPComponent)(const Real &xx, const Real &yy));
00273
00286  void BindVectorFieldQComponent(
00287      Real (*VectorFieldQComponent)(const Real &xx, const Real &yy));
00288
00289  std::vector<Real> discrete_domain_x_;
00290  std::vector<Real> discrete_domain_y_;
00291  std::vector<Real> discrete_field_;
00292
00293  FieldNature nature_;
00294
00295  Real west_bndy_;
00296  Real east_bndy_;
00297  int num_cells_x_;
00298  Real delta_x_;
00299
00300  Real south_bndy_;
00301  Real north_bndy_;
00302  int num_cells_y_;
00303  Real delta_y_;
00304 };
00305 }
00306 #endif // End of: MTK_INCLUDE_UNI_STG_GRID_2D_H_

```

## 17.51 Makefile.inc File Reference

## 17.52 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 DOCFEILNAME = doc_config.dxcfc
00205 DOC         = $(BASE)/doc
00206 DOCFEIL     = $(BASE)/$(DOCFEILNAME)

```

## 17.53 README.md File Reference

### 17.54 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
00006 ## 1. Description
00007
00008 We define numerical methods that are based on discretizations preserving the
00009 properties of their continuum counterparts to be **mimetic**.
00010
00011 The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical
00012 methods. It is arranged as a set of classes for **mimetic quadratures**,
00013 **mimetic interpolation**, and **mimetic finite differences** methods for the
00014 numerical solution of ordinary and partial differential equations.
00015
00016 An older version of this library is available outside of GitHub... just email me
00017 about it, and you can have it... it is ugly, yet it is functional and more
00018 complete.
00019 -----
00020
00021 ## 2. Dependencies
00022
00023 This README assumes all of these dependencies are installed in the following
00024 folder:
00025
00026 ```
00027 $(HOME)/Libraries/
00028 ```
00029
00030 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00031 routines for the internal computation on some of the layers. However, ATLAS
00032 requires both BLAS and LAPACK in order to create their optimized distributions.
00033 Therefore, the following dependencies tree arises:
00034
00035 ### For Linux:
00036
00037 1. LAPACK - Available from: http://www.netlib.org/lapack/
00038 1. BLAS - Available from: http://www.netlib.org/blas/
00039
00040 2. GLPK - Available from: https://www.gnu.org/software/glpk/
00041
00042 3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00043 1. LAPACK - Available from: http://www.netlib.org/lapack/
00044 1. BLAS - Available from: http://www.netlib.org/blas/
00045
00046 4. (Optional) Valgrind - Available from: http://valgrind.org/
00047
00048 5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00049
00050 ### For OS X:
00051

```

```

00052 1. GLPK - Available from: https://www.gnu.org/software/glpk/
00053
00054
00055 ## 3. Installation
00056
00057 ### PART 1. CONFIGURATION OF THE MAKEFILE.
00058
00059 The following steps are required to build and test the MTK. Please use the
00060 accompanying 'Makefile.inc' file, which should provide a solid template to
00061 start with. The following command provides help on the options for make:
00062
00063 ```
00064 $ make help
00065 -----
00066 Makefile for the MTK.
00067
00068 Options are:
00069 - all: builds the library, the tests, and examples.
00070 - mtklib: builds the library.
00071 - test: builds the test files.
00072 - example: builds the examples.
00073
00074 - testall: runs all the tests.
00075
00076 - gendoc: generates the documentation for the library.
00077
00078 - clean: cleans all the generated files.
00079 - cleanlib: cleans the generated archive and object files.
00080 - cleantest: cleans the generated tests executables.
00081 - cleanexample: cleans the generated examples executables.
00082 -----
00083 ```
00084
00085 ### PART 2. BUILD THE LIBRARY.
00086
00087 ```
00088 $ make
00089 ```
00090
00091 If successful you'll read (before building the tests and examples):
00092
00093 ```
00094 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
00095 ```
00096
00097 Examples and tests will also be built.
00098
00099
00100 ## 4. Frequently Asked Questions
00101
00102 Q: Why haven't you guys implemented GBS to build the library?
00103 A: I'm on it as we speak! ;)
00104
00105 Q: Is there any main reference when it comes to the theory on Mimetic Methods?
00106 A: Yes! Check: http://www.csrc.sdsu.edu/mimetic-book
00107
00108 Q: Do I need to generate the documentation myself?
00109 A: You can if you want to... but if you DO NOT want to, just go to our website.
00110
00111
00112 ## 5. Contact, Support, and Credits
00113
00114 The MTK is developed by researchers and adjuncts to the
00115 [Computational Science Research Center (CSRC)] (http://www.csrc.sdsu.edu/)
00116 at [San Diego State University (SDSU)] (http://www.sdsu.edu/).
00117
00118 Developers are members of:
00119
00120 1. Mimetic Numerical Methods Research and Development Group.
00121 2. Computational Geoscience Research and Development Group.
00122 3. Ocean Modeling Research and Development Group.
00123
00124 Currently the developers are:
00125
00126 - *Eduardo J. Sanchez, Ph.D. - esanchez@mail.sdsu.edu - @ejspeiro
00127 - Jose E. Castillo, Ph.D. - jcastillo@mail.sdsu.edu
00128 - Guillermo F. Miranda, Ph.D. - unigrav@hotmail.com
00129 - Christopher P. Paolini, Ph.D. - paolini@engineering.sdsu.edu
00130 - Angel Boda.
00131 - Johnny Corbino.
00132 - Raul Vargas-Navarro.

```

```

00133
00134 Finally, please feel free to contact me with suggestions or corrections:
00135
00136 **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00137
00138 Thanks and happy coding!

```

## 17.55 src/mtk\_blas\_adapter.cc File Reference

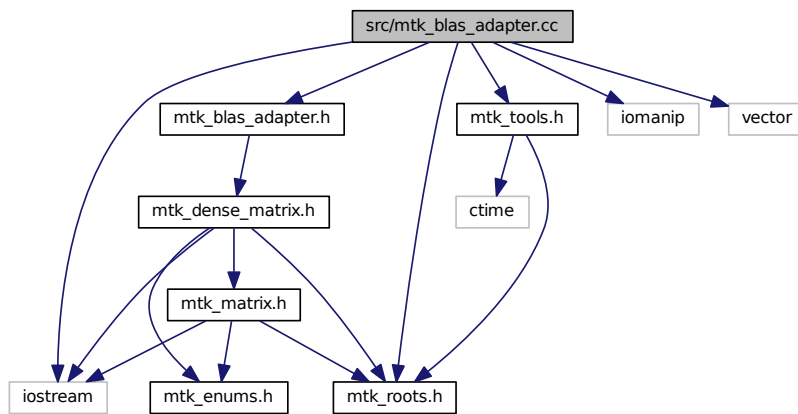
Adapter class for the BLAS API.

```

#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)

### 17.55.1 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](#).

## 17.56 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
00049 may be used to endorse or promote products derived from this software without
00050 specific prior written permission.
00051
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```

```
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 dnm2_(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 dnorm2_(&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(
00359     mtk::Real *computed,
00360     mtk::Real *known,
00361     int length) {
00362
00363     #ifdef MTK_PERFORM_PREVENTIONS
00364     mtk::Tools::Prevent(computed == nullptr, __FILE__, __LINE__, __func__);
00365     mtk::Tools::Prevent(known == nullptr, __FILE__, __LINE__, __func__);
00366     #endif
00367
00368     mtk::Real norm_2_computed{mtk::BLASAdapter::RealNRM2(known, length)};
00369
00370     mtk::Real alpha{-mtk::kOne};
00371
00372     mtk::BLASAdapter::RealAXPY(alpha, known, computed, length);
00373
00374     mtk::Real norm_2_difference{mtk::BLASAdapter::RealNRM2(computed,
00375     length)};
00376
00377     return norm_2_difference/norm_2_computed;
00378 }
00379
00380 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00381                                    mtk::DenseMatrix &aa,
00382                                    mtk::Real *xx,
00383                                    mtk::Real &beta,
00384                                    mtk::Real *yy) {
00385
00386     // Make sure input matrices are row-major ordered.
00387
00388     if (aa.matrix_properties().ordering() ==
00389         mtk::COL_MAJOR) {
00390         aa.OrderRowMajor();
00391     }

```

```

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(
00410     mtk::DenseMatrix &aa,
00411                                     mtk::DenseMatrix &bb) {
00412     #ifdef MTK_PERFORM_PREVENTIONS
00413     mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00414                         __FILE__, __LINE__, __func__);
00415     #endif
00416
00417     if (aa.matrix_properties().ordering() ==
00418         mtk::COL_MAJOR) {
00419         aa.OrderRowMajor();
00420     }
00421     if (bb.matrix_properties().ordering() ==
00422         mtk::COL_MAJOR) {
00423         bb.OrderRowMajor();
00424     }
00425
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
00447     #ifdef MTK_PRECISION_DOUBLE
00448     dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00449           bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00450     #else
00451     sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00452           bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00453     #endif
00454
00455     #if MTK_VERBOSE_LEVEL > 12
00456     std::cout << "cc_col_maj_ord =" << std::endl;
00457     std::cout << cc_col_maj_ord << std::endl;
00458     #endif
00459
00460     cc_col_maj_ord.OrderRowMajor();
00461
00462     return cc_col_maj_ord;
00463 }
00464
00465
00466 mtk::DenseMatrix mtk::BLASAdapter::RealDenseSM(
00467     mtk::Real alpha,
00468                                     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 }

```

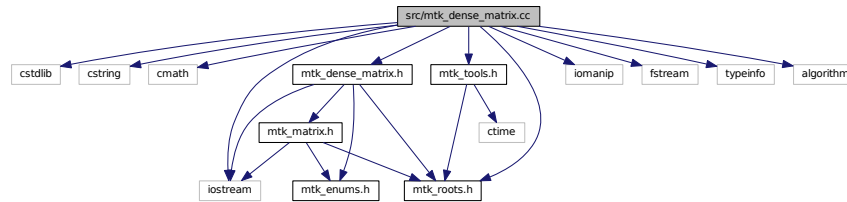
## 17.57 src/mtk\_dense\_matrix.cc File Reference

```

#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)`

## 17.58 mtk\_dense\_matrix.cc

```

00001
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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() ==
00083         mtk::COL_MAJOR) {
00084         std::swap(mm, nn);
00085     }
00086     for (int ii = 0; ii < mm; ii++) {
00087         int offset{ii*nn};
00088         for (int jj = 0; jj < nn; jj++) {
00089             mtk::Real value = in.data_[offset + jj];
00090             stream << std::setw(9) << value;
00091         }
00092         stream << std::endl;
00093     }
00094     if (in.matrix_properties_.ordering() ==
00095         mtk::COL_MAJOR) {
00096         std::swap(mm, nn);
00097     }
00098     return stream;
00099 }
00100 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
00101 mtk::DenseMatrix &in) {
00102
00103     if(this == &in) {
00104         return *this;
00105     }
00106     matrix_properties_.set_storage(in.
00107 matrix_properties_.storage());
00108     matrix_properties_.set_ordering(in.
00109 matrix_properties_.ordering());
00110
00111     auto aux = in.matrix_properties_.num_rows();
00112     matrix_properties_.set_num_rows(aux);
00113
00114     aux = in.matrix_properties().num_cols();
00115     matrix_properties_.set_num_cols(aux);
00116
00117     aux = in.matrix_properties().num_zero();
00118     matrix_properties_.set_num_zero(aux);
00119
00120     aux = in.matrix_properties().num_null();
00121     matrix_properties_.set_num_null(aux);
00122
00123     auto num_rows = matrix_properties_.num_rows();
00124     auto num_cols = matrix_properties_.num_cols();
00125
00126     delete [] data_;
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     delete [] data_;
00314     data_ = nullptr;
00315 }
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     return matrix_properties_.num_rows();
00335 }
00336
00337
00338 int mtk::DenseMatrix::num_cols() const noexcept {
00339     return matrix_properties_.num_cols();
00340 }
00341
00342
00343 mtk::Real* mtk::DenseMatrix::data() const noexcept {
00344     return data_;
00345 }
00346
00347
00348 mtk::Real mtk::DenseMatrix::GetValue(
    const int &mm,
    const int &nn) const noexcept {
00349
00350     #ifdef MTK_PERFORM_PREVENTIONS
00351     mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00352     mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00353     #endif
00354
00355     return data_[mm*matrix_properties_.num_cols() + nn];
00356 }
00357
00358
00359
00360 void mtk::DenseMatrix::SetValue(
    const int &mm,
    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
00375     mtk::Real *data_transposed{}; // Buffer.
00376
00377     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00378     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00379
00380     try {
00381         data_transposed = new mtk::Real[mm*nn];
00382     } catch (std::bad_alloc &memory_allocation_exception) {
00383         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00384             std::endl;
00385         std::cerr << memory_allocation_exception.what() << std::endl;
00386     }
00387     memset(data_transposed,
00388         mtk::kZero,
00389         sizeof(data_transposed[0])*mm*nn);
00390
00391     // Assign the values to their transposed position.
00392     for (auto ii = 0; ii < mm; ++ii) {
00393         for (auto jj = 0; jj < nn; ++jj) {
00394             data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00395         }
00396     }
00397
00398     // Swap pointers.
00399     auto tmp = data_; // Temporal holder.
00400     data_ = data_transposed;
00401     delete [] tmp;
00402     tmp = nullptr;
00403
00404     matrix_properties_.set_num_rows(nn);
00405     matrix_properties_.set_num_cols(mm);
00406 }
00407
00408 void mtk::DenseMatrix::OrderRowMajor() {
00409
00410     if (matrix_properties_.ordering() == mtk::COL_MAJOR) {
00411
00412         mtk::Real *data_transposed{}; // Buffer.
00413
00414         int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00415         int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00416
00417         try {
00418             data_transposed = new mtk::Real[mm*nn];
00419         } catch (std::bad_alloc &memory_allocation_exception) {
00420             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00421                 std::endl;
00422             std::cerr << memory_allocation_exception.what() << std::endl;
00423         }
00424         memset(data_transposed,
00425             mtk::kZero,
00426             sizeof(data_transposed[0])*mm*nn);
00427
00428         // Assign the values to their transposed position.
00429         std::swap(mm, nn);
00430         for (auto ii = 0; ii < mm; ++ii) {
00431             for (auto jj = 0; jj < nn; ++jj) {
00432                 data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00433             }
00434         }
00435         std::swap(mm, nn);
00436
00437         // Swap pointers.
00438         auto tmp = data_; // Temporal holder.
00439         data_ = data_transposed;
00440         delete [] tmp;
00441         tmp = nullptr;
00442

```

```

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
00455         mtk::Real *data_transposed{}; // Buffer.
00456
00457         int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00458         int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00459
00460         try {
00461             data_transposed = new mtk::Real[mm*nn];
00462         } catch (std::bad_alloc &memory_allocation_exception) {
00463             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00464                 std::endl;
00465             std::cerr << memory_allocation_exception.what() << std::endl;
00466         }
00467         memset(data_transposed,
00468             mtk::kZero,
00469             sizeof(data_transposed[0])*mm*nn);
00470
00471         // Assign the values to their transposed position.
00472         for (auto ii = 0; ii < mm; ++ii) {
00473             for (auto jj = 0; jj < nn; ++jj) {
00474                 data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00475             }
00476         }
00477
00478         // Swap pointers.
00479         auto tmp = data_; // Temporal holder.
00480         data_ = data_transposed;
00481         delete [] tmp;
00482         tmp = nullptr;
00483
00484         matrix_properties_.set_ordering(mtk::COL_MAJOR);
00485     }
00486 }
00487
00488 }
00489
00490 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
    mtk::DenseMatrix &aa,
                                const mtk::DenseMatrix &bb) {
00491
00492     int row_offset{}; // Offset for rows.
00493     int col_offset{}; // Offset for rows.
00494
00495     mtk::Real aa_factor{}; // Used in computation.
00496
00497     // Auxiliary variables:
00498     auto aux1 = aa.matrix_properties_.num_rows()*bb.
matrix_properties_.num_rows();
00499     auto aux2 = aa.matrix_properties_.num_cols()*bb.
matrix_properties_.num_cols();
00500
00501     mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00502
00503     int kk_num_cols(output.matrix_properties_.num_cols()); // Aux.
00504
00505     auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00506     auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00507     auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00508     auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00509
00510     for (auto ii = 0; ii < mm; ++ii) {
00511         row_offset = ii*pp;
00512         for (auto jj = 0; jj < nn; ++jj) {
00513             col_offset = jj*qq;
00514             aa_factor = aa.data_[ii*nn + jj];
00515             for (auto ll = 0; ll < pp; ++ll) {
00516                 for (auto oo = 0; oo < qq; ++oo) {
00517                     auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00518                     output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00519                 }
00520             }
00521         }
00522     }
00523 }
00524

```



```

00525     output.matrix_properties_.set_storage(mtk::DENSE);
00526     output.matrix_properties_.set_ordering(
00527         mtk::ROW_MAJOR);
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 }

```

## 17.59 src/mtk\_div\_1d.cc File Reference

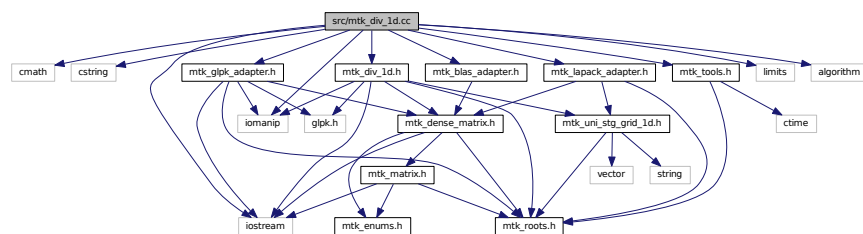
Implements the class Div1D.

```

#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)`

### 17.59.1 Detailed Description

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

#### Author

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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](#).

## 17.60 mtk\_div\_1d.cc

```

00001
00015 /*
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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
00028 2. Redistributions of source code must be done through direct
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```

```

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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_div_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Div1D &in) {
00080
00081     stream << "divergence_[0] = " << std::setw(9) << in.divergence_[0] <<
00082         std::endl;
00083
00084     stream << "divergence_[1:" << in.order_accuracy_ << "] = ";
00085     for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00086         stream << std::setw(9) << in.divergence_[ii] << " ";
00087     }
00088     stream << std::endl;
00089
00090     if (in.order_accuracy_ > 2) {
00091
00092         stream << "divergence_[ " << in.order_accuracy_ + 1 << ":" <<
00093             2*in.order_accuracy_ << "] = ";
00094         for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
00095             order_accuracy_; ++ii) {
00096             stream << std::setw(9) << in.divergence_[ii] << " ";
00097         }
00098         stream << std::endl;
00099
00100         auto offset = (2*in.order_accuracy_ + 1);
00101         int mm{};
00102         for (auto ii = 0; ii < in.dim_null_; ++ii) {
00103             stream << "divergence_[ " << offset + mm << ":" <<
00104                 offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00105             for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00106                 auto value = in.divergence_[offset + mm];
00107                 stream << std::setw(9) << value << " ";
00108                 ++mm;
00109             }
00110             stream << std::endl;
00111         }
00112     }
00113 }
00114
00115 return stream;
00116 }
00117
00118 mtk::Div1D::Div1D():
00119     order_accuracy_(mtk::kDefaultOrderAccuracy),
00120     dim_null_(),
00121     num_bndy_coeffs_(),
00122     divergence_length_(),
00123     minrow_(),
00124     row_(),
00125     coeffs_interior_(),
00126     prem_apps_(),
00127     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
00196
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
00227
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
00256
00257       abort_construction = ComputePreliminaryApproximations();
00258
00259       #ifdef MTK_PERFORM_PREVENTIONS
00260       if (!abort_construction) {
00261           std::cerr << "Could NOT complete stage 2.2." << std::endl;
00262           std::cerr << "Exiting..." << std::endl;
00263           return false;
00264       }
00265       #endif
00266
00267
00268       abort_construction = ComputeWeights();
00269
00270       #ifdef MTK_PERFORM_PREVENTIONS
00271       if (!abort_construction) {
00272           std::cerr << "Could NOT complete stage 2.3." << std::endl;
00273           std::cerr << "Exiting..." << std::endl;
00274           return false;
00275       }
00276       #endif
00277
00278
00279       abort_construction = ComputeStencilBoundaryGrid();
00280
00281       #ifdef MTK_PERFORM_PREVENTIONS
00282       if (!abort_construction) {
00283           std::cerr << "Could NOT complete stage 2.4." << std::endl;
00284           std::cerr << "Exiting..." << std::endl;
00285           return false;
00286       }
00287       #endif
00288
00289
00290   } // End of: if (dim_null_ > 0);
00291
00292
00293
00294
00295   // Once we have the following three collections of data:
00296   //   (a) the coefficients for the interior,
00297   //   (b) the coefficients for the boundary (if it applies),
00298   //   (c) and the weights (if it applies),
00299   // we will store everything in the output array:
00300
00301   abort_construction = AssembleOperator();
00302

```

```

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     return num_bndy_coeffs_;
00317 }
00318
00319
00320 mtk::Real *mtk::Div1D::coeffs_interior() const {
00321     return coeffs_interior_;
00322 }
00323
00324
00325 mtk::Real *mtk::Div1D::weights_crs() const {
00326     return weights_crs_;
00327 }
00328
00329
00330 mtk::Real *mtk::Div1D::weights_cbs() const {
00331     return weights_cbs_;
00332 }
00333
00334
00335 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00336     mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00337
00338     auto counter = 0;
00339     for (auto ii = 0; ii < dim_null_; ++ii) {
00340         for (auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00341             xx.SetValue(ii, jj, divergence_[2*order_accuracy_ + 1 + counter]);
00342             counter++;
00343         }
00344     }
00345     return xx;
00346 }
00347
00348
00349
00350 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(
00351     const UniStgGrid1D &grid) const {
00352     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00353
00354     #ifdef MTK_PERFORM_PREVENTIONS
00355     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00356     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00357     #endif
00358
00359     mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00360
00361     int dd_num_rows = nn + 2;
00362     int dd_num_cols = nn + 1;
00363     int elements_per_row = num_bndy_coeffs_;
00364     int num_extra_rows = dim_null_;
00365
00366     // Output matrix featuring sizes for divergence operators.
00367     mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00368
00369     auto ee_index = 0;
00370     for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00371         auto cc = 0;
00372         for (auto jj = 0; jj < dd_num_rows; jj++) {
00373             if (cc >= elements_per_row) {
00374                 out.SetValue(ii, jj, mtk::kZero);
00375             } else {
00376                 out.SetValue(ii, jj, mim_bndy_[ee_index++] * inv_delta_x);
00377                 cc++;
00378             }
00379         }
00380     }
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
00395
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
00416
00417     mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00418
00419     try {
00420         pp = new mtk::Real[order_accuracy_];
00421     } catch (std::bad_alloc &memory_allocation_exception) {
00422         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00423             std::endl;
00424         std::cerr << memory_allocation_exception.what() << std::endl;
00425     }
00426     memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00427
00428     #ifdef MTK_PRECISION_DOUBLE
00429     pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00430     #else
00431     pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00432     #endif
00433
00434     for (auto ii = 1; ii < order_accuracy_; ++ii) {
00435         pp[ii] = pp[ii - 1] + mtk::kOne;
00436     }
00437
00438     #if MTK_VERBOSE_LEVEL > 3
00439     std::cout << "pp = " << std::endl;
00440     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00441         std::cout << std::setw(12) << pp[ii];
00442     }
00443     std::cout << std::endl << std::endl;
00444     #endif
00445
00446
00447     bool transpose{false};
00448
00449     mtk::DenseMatrix vander_matrix(pp,
00450                                     order_accuracy_,
00451                                     order_accuracy_,
00452                                     transpose);
00453
00454     #if MTK_VERBOSE_LEVEL > 4
00455     std::cout << "vander_matrix = " << std::endl;
00456     std::cout << vander_matrix << std::endl;
00457     #endif
00458
00459     try {
00460         coeffs_interior_ = new mtk::Real[order_accuracy_];
00461     } catch (std::bad_alloc &memory_allocation_exception) {
00462         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00463             std::endl;
00464         std::cerr << memory_allocation_exception.what() << std::endl;
00465     }
00466     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
00484 int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00485                                               coeffs_interior_)};
00486
00487 #ifdef MTK_PERFORM_PREVENTIONS
00488 if (!info) {
00489     std::cout << "System solved! Interior stencil attained!" << std::endl;
00490     std::cout << std::endl;
00491 }
00492 else {
00493     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00494     std::cerr << "Exiting..." << std::endl;
00495     return false;
00496 }
00497 #endif
00498
00499 #if MTK_VERBOSE_LEVEL > 3
00500 std::cout << "coeffs_interior_ =" << std::endl;
00501 for (auto ii = 0; ii < order_accuracy_; ++ii) {
00502     std::cout << std::setw(12) << coeffs_interior_[ii];
00503 }
00504 std::cout << std::endl << std::endl;
00505 #endif
00506
00507 delete [] pp;
00508 pp = nullptr;
00509
00510 return true;
00511 }
00512
00513 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00514
00515     mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00516
00517     try {
00518         gg = new mtk::Real[num_bndy_coeffs_];
00519     } catch (std::bad_alloc &memory_allocation_exception) {
00520         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00521             std::endl;
00522         std::cerr << memory_allocation_exception.what() << std::endl;
00523     }
00524     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00525
00526 #ifdef MTK_PRECISION_DOUBLE
00527     gg[0] = -1.0/2.0;
00528 #else
00529     gg[0] = -1.0f/2.0f;
00530 #endif
00531
00532 for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00533     gg[ii] = gg[ii - 1] + mtk::kOne;
00534 }
00535
00536 #if MTK_VERBOSE_LEVEL > 3
00537 std::cout << "gg =" << std::endl;
00538 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00539     std::cout << std::setw(12) << gg[ii];
00540 }
00541 std::cout << std::endl << std::endl;
00542 #endif
00543
00544 bool tran{true}; // Should I transpose the Vandermonde matrix.
00545
00546 mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00547
00548 #if MTK_VERBOSE_LEVEL > 4
00549 std::cout << "vv_west_t =" << std::endl;

```



```

00555     std::cout << vv_west_t << std::endl;
00556     #endif
00557
00558
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
00567
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
00589
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 scalars.
00640 // An example of the system to solve, for k = 8, is:
00641 //
00642 // SUBK*scalars = II_or
00643 //
00644 // | 0.386018 -0.0339244 -0.129478 | | 1 0 0 |
00645 // | -0.119774 0.0199423 0.0558632 |*scalars = | 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 scalars... 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 scalars:" << 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
00693     mtk::Real *gg{}; // Generator vector for the first approximation.
00694
00695     try {
00696         gg = new mtk::Real[num_bndy_coeffs_];
00697     } catch (std::bad_alloc &memory_allocation_exception) {
00698         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00699             std::endl;
00700         std::cerr << memory_allocation_exception.what() << std::endl;
00701     }
00702     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00703
00704     #ifdef MTK_PRECISION_DOUBLE
00705     gg[0] = -1.0/2.0;
00706     #else
00707     gg[0] = -1.0f/2.0f;
00708     #endif
00709     for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00710         gg[ii] = gg[ii - 1] + mtk::kOne;
00711     }
00712
00713     #if MTK_VERBOSE_LEVEL > 3
00714     std::cout << "gg0 =" << std::endl;
00715     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00716         std::cout << std::setw(12) << gg[ii];
00717     }
00718 }

```

```

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
00735     for (auto ll = 0; ll < dim_null_; ++ll) {
00736
00737         // Re-check new generator vector for every iteration except for the first.
00738         #if MTK_VERBOSE_LEVEL > 3
00739         if (ll > 0) {
00740             std::cout << "gg" << ll << " =" << std::endl;
00741             for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00742                 std::cout << std::setw(12) << gg[ii];
00743             }
00744             std::cout << std::endl << std::endl;
00745         }
00746         #endif
00747
00748         bool transpose{false};
00749
00750         mtk::DenseMatrix AA_(gg,
00751             num_bndy_coeffs_, order_accuracy_ + 1,
00752             transpose);
00753
00754         #if MTK_VERBOSE_LEVEL > 4
00755         std::cout << "AA_" << ll << " =" << std::endl;
00756         std::cout << AA_ << std::endl;
00757         #endif
00758
00759         mtk::Real *ob{};
00760
00761         auto ob_ld = num_bndy_coeffs_;
00762
00763         try {
00764             ob = new mtk::Real[ob_ld];
00765         } catch (std::bad_alloc &memory_allocation_exception) {
00766             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00767                 std::endl;
00768             std::cerr << memory_allocation_exception.what() << std::endl;
00769         }
00770         memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00771
00772         ob[1] = mtk::kOne;
00773
00774         #if MTK_VERBOSE_LEVEL > 4
00775         std::cout << "ob =" << std::endl << std::endl;
00776         for (auto ii = 0; ii < ob_ld; ++ii) {
00777             std::cout << std::setw(12) << ob[ii] << std::endl;
00778         }
00779         std::cout << std::endl;
00780         #endif
00781
00782         // However, this is an under-determined system of equations. So we can not
00783         // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00784         // our LAPACKAdapter class.
00785
00786         int info_{
00787             mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
00788                 ob, ob_ld)};
00789
00790         #ifdef MTK_PERFORM_PREVENTIONS
00791         if (!info_) {
00792             std::cout << "System successfully solved!" << std::endl << std::endl;
00793         } else {
00794             std::cerr << "Error solving system! info = " << info_ << std::endl;
00795         }
00796         #endif
00797     }

```

```

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
00813
00814
00815     // This implies a DAXPY operation. However, we must construct the arguments
00816     // for this operation.
00817
00818     // Save them into the ob_bottom array:
00819
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
00844
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
00872     // We save the recently scaled solution, into an array containing these.
00873     // We can NOT start building the pi matrix, simply because I want that part
00874     // to be separated since its construction depends on the algorithm we want
00875     // to implement.
00876
00877     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00878         prem_apps_[ii*dim_null_ + 11] = ob[ii];
00879     }
00880
00881     // After the first iteration, simply shift the entries of the last
00882     // generator vector used:
00883     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00884         gg[ii]--;
00885     }
00886
00887     // Garbage collection for this loop:
00888     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 compute the weights as in the CRSA.
00914     mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00915
00916     // Assemble the pi matrix using:
00917     // 1. The collection of scaled preliminary approximations.
00918     // 2. The collection of coefficients approximating at the interior.
00919     // 3. The scaled basis for the null-space.
00920
00921     // 1.1. Process array of scaled preliminary approximations.
00922
00923     // These are queued in scaled_solutions. Each one of these, will be a column
00924     // of the pi matrix:
00925     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00926         for (auto jj = 0; jj < dim_null_; ++jj) {
00927             pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00928                 prem_apps_[ii*dim_null_ + jj];
00929         }
00930     }
00931
00932     // 1.2. Add columns from known stencil approximating at the interior.
00933
00934     // However, these must be padded by zeros, according to their position in the
00935     // final pi matrix:
00936     auto mm = 0;
00937     for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00938         for (auto ii = 0; ii < order_accuracy_; ++ii) {
00939             pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00940                 coeffs_interior_[ii];
00941         }
00942         ++mm;
00943     }
00944
00945     rat_basis_null_space_.OrderColMajor();
00946
00947     #if MTK_VERBOSE_LEVEL > 4
00948     std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00949     std::cout << rat_basis_null_space_ << std::endl;
00950     #endif
00951
00952     // 1.3. Add final set of columns: rational basis for null-space.
00953     for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
00954          jj < num_bndy_coeffs_ - 1;
00955          ++jj) {
00956         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00957             auto og =
00958                 (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00959             auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00960             pi.data()[de] = rat_basis_null_space_.data()[og];
00961         }
00962     }
00963
00964     #if MTK_VERBOSE_LEVEL > 3
00965     std::cout << "coeffs_interior_" << std::endl;
00966     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00967         std::cout << std::setw(12) << coeffs_interior_[ii];
00968     }
00969 }

```

```

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(
01029     pi,
01030         weights_cbs_,
01031         weights_ld)};
01032
01033 #ifdef MTK_PERFORM_PREVENTIONS
01034 if (!info) {
01035     std::cout << "System successfully solved!" << std::endl << std::endl;
01036 } else {
01037     std::cerr << "Error solving system! info = " << info << std::endl;
01038 }
01039 #endif
01040
01041 #if MTK_VERBOSE_LEVEL > 3
01042     std::cout << "hh =" << std::endl;
01043     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01044         std::cout << std::setw(11) << hh[ii] << std::endl;
01045     }
01046     std::cout << std::endl;
01047 #endif
01048
01049 // Preserve the original weights for research.
01050
01051 try {
01052     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     int minrow_{std::numeric_limits<int>::infinity()};
01073
01074     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
01075     order_accuracy_)};
01076     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01077
01079     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01080
01081     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01082         for (auto jj = 0; jj < dim_null_; ++jj) {
01083             phi.data()[ii*(order_accuracy_ + 1) + jj] = prem_apps_[ii*dim_null_ + jj];
01084         }
01085     }
01086
01087     int aux{}; // Auxiliary variable.
01088     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01089         for (auto ii = 0; ii < order_accuracy_; ++ii) {
01090             phi.data()[ii*(order_accuracy_ + 1) + jj] = coeffs_interior[ii];
01091         }
01092         ++aux;
01093     }
01094
01095     for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01096         for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01097             phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01098         }
01099     }
01100
01101     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01102         for (auto ii = 0; ii < dim_null_; ++ii) {
01103             phi.data()[ii*(order_accuracy_ + 1) + jj] = prem_apps_[ii*dim_null_ + jj];
01104         }
01105     }
01106
01107     for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
01108         for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01109             auto swap = phi.data()[ii*order_accuracy_+jj];
01110             phi.data()[ii*order_accuracy_ + jj] =
01111                 phi.data()[ii*(order_accuracy_ - 1) + jj];
01112             phi.data()[ii*(order_accuracy_ - 1) + jj] = swap;
01113         }
01114     }
01115
01116     #if MTK_VERBOSE_LEVEL > 4
01117     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01118     std::cout << phi << std::endl;
01119     #endif
01120
01121     mtk::Real *lamed{}; // Used to build big lambda.
01122
01123     try {
01124         lamed = new mtk::Real[dim_null_];
01125     } catch (std::bad_alloc &memory_allocation_exception) {
01126         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01127         std::endl;
01128         std::cerr << memory_allocation_exception.what() << std::endl;
01129     }
01130     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
01169     for(auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01170         normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01171 data(),
01172                                     order_accuracy_ + 1,
01173                                     order_accuracy_,
01174                                     order_accuracy_,
01175                                     hh,
01176                                     weights_cbs_,
01177                                     row_,
01178                                     mimetic_threshold_,
01179                                     copy_result);
01180
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
01203     // After we know which row yields the smallest relative norm that row is
01204     // chosen to be the objective function and the result of the optimizer is
01205     // chosen to be the new weights_.
01206
01207     #if MTK_VERBOSE_LEVEL > 2
01208     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01209         minrow_ + 1 << std::endl;
01210     std::cout << std::endl;
01211     #endif
01212
01213     copy_result = 1;
01214     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
01251     mtk::Real *lambda{}; // Collection of bottom values from weights_.
01252
01253     try {
01254         lambda = new mtk::Real[dim_null_];
01255     } catch (std::bad_alloc &memory_allocation_exception) {
01256         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01257             std::endl;
01258         std::cerr << memory_allocation_exception.what() << std::endl;
01259     }
01260     memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01261
01262     for (auto ii = 0; ii < dim_null_; ++ii) {
01263         lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01264     }
01265
01266     #if MTK_VERBOSE_LEVEL > 3
01267     std::cout << "lambda =" << std::endl;
01268     for (auto ii = 0; ii < dim_null_; ++ii) {
01269         std::cout << std::setw(12) << lambda[ii] << std::endl;
01270     }
01271     std::cout << std::endl;
01272     #endif
01273
01274     mtk::Real *alpha{}; // Collection of alpha values.
01275
01276     try {
01277         alpha = new mtk::Real[dim_null_];
01278     } catch (std::bad_alloc &memory_allocation_exception) {
01279         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01280             std::endl;
01281         std::cerr << memory_allocation_exception.what() << std::endl;
01282     }
01283     memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01284
01285     for (auto ii = 0; ii < dim_null_; ++ii) {
01286         alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01287     }
01288
01289     #if MTK_VERBOSE_LEVEL > 3
01290     std::cout << "alpha =" << std::endl;
01291     for (auto ii = 0; ii < dim_null_; ++ii) {
01292         std::cout << std::setw(12) << alpha[ii] << std::endl;
01293     }
01294     std::cout << std::endl;
01295

```

```

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
01374     divergence_[0] = order_accuracy_;
01375
01376     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01377         divergence_[ii + 1] = coeffs_interior_[ii];
01378     }
01379 }

```

```

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 }

```

## 17.61 src/mtk\_div\_2d.cc File Reference

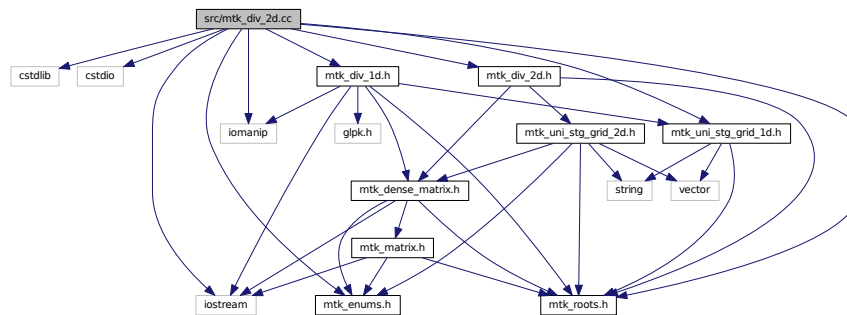
Implements the class Div2D.

```

#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:



### 17.61.1 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](#).

**17.62 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,
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00038
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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_ld.h"
00066 #include "mtk_div_ld.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() {}

```

```

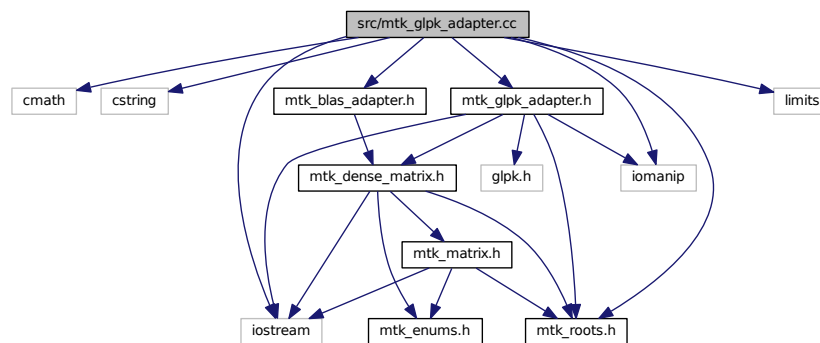
00078
00079 bool mtk::Div2D::ConstructDiv2D(const
    mtk::UniStgGrid2D &grid,
00080                                     int order_accuracy,
00081                                     mtk::Real mimetic_threshold) {
00082
00083     int num_cells_x = grid.num_cells_x();
00084     int num_cells_y = grid.num_cells_y();
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 }

```

## 17.63 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:
```



### 17.63.1 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](#).

## 17.64 mtk\_glpk\_adapter.cc

```
00001
00019 /*
```

```

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00027 and a copy of the modified files should be reported once modifications are
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00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
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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
00078                                     int nrows,
00079                                     int ncols,
00080                                     int kk,
00081                                     mtk::Real *hh,
00082                                     mtk::Real *qq,
00083                                     int robjective,
00084                                     mtk::Real mimetic_threshold,
00085                                     int copy) {
00086
00087     #if MTK_DEBUG_LEVEL > 0
00088     char mps_file_name[18]; // File name for the MPS files.
00089     #endif
00090     char rname[5];          // Row name.
00091     char cname[5];          // Column name.
00092
00093     glp_prob *lp; // Linear programming problem.
00094
00095     int *ia; // Array for the problem.
00096     int *ja; // Array for the problem.
00097
00098     int problem_size; // Size of the problem.
00099     int lp_nrows;     // Number of rows.
00100     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 x1;         // 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
00121
00122
00123 problem_size = lp_nrows*lp_ncols + 1;
00124
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
00193     glp_add_rows(lp, lp_nrows);
00194
00195     for (ii = 1; ii <= lp_nrows; ++ii) {
00196         sprintf(rname, "R%02d",ii);
00197         glp_set_row_name(lp, ii, rname);
00198     }
00199
00200     glp_add_cols(lp, lp_ncols);
00201
00202     for (ii = 1; ii <= lp_ncols; ++ii) {
00203         sprintf(cname, "Q%02d",ii);
00204         glp_set_col_name (lp, ii, cname);
00205     }
00206
00207     #if MTK_DEBUG_LEVEL>0
00208     std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00209     #endif
00210     for (jj = 0; jj < kk; ++jj) {
00211         objective[glp_index] = A[jj + robjective * ncols];
00212         glp_index++;
00213     }
00214     #if MTK_DEBUG_LEVEL >0
00215     std::cout << std::endl;
00216     #endif
00217
00218     glp_index = 1;
00219     rhs[0] = mtk::kZero;
00220     for (ii = 0; ii <= lp_nrows; ++ii) {
00221         if (ii != robjective) {
00222             rhs[glp_index] = hh[ii];
00223             glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00224             glp_index++;
00225         }
00226     }
00227
00228     #if MTK_DEBUG_LEVEL > 0
00229     std::cout << "rhs =" << std::endl;
00230     for (auto ii = 0; ii < lp_nrows; ++ii) {
00231         std::cout << std::setw(15) << rhs[ii] << std::endl;
00232     }
00233     std::cout << std::endl;
00234     #endif
00235
00236     for (ii = 1; ii <= lp_ncols; ++ii) {
00237         glp_set_obj_coef (lp, ii, objective[ii]);
00238     }
00239
00240     for (ii = 1; ii <= lp_ncols; ++ii) {
00241         glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00242     }
00243
00244     glp_index = 1;
00245     for (ii = 0; ii <= kk; ++ii) {
00246         for (jj = 0; jj < kk; ++jj) {
00247             if (ii != robjective) {
00248                 ar[glp_index] = A[jj + ii * ncols];
00249                 glp_index++;
00250             }
00251         }
00252     }
00253
00254     glp_index = 0;
00255     for (ii = 1; ii < problem_size; ++ii) {
00256         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
00283 glp_simplex (lp, nullptr);
00284
00285 // Check status of the solution.
00286
00287 if (glp_get_status(lp) == GLP_OPT) {
00288
00289     for(ii = 1; ii <= lp_ncols; ++ii) {
00290         err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp, ii);
00291     }
00292
00293     #if MTK_DEBUG_LEVEL > 0
00294     obj_value = glp_get_obj_val (lp);
00295     std::cout << std::setw(12) << "CBS" << std::endl;
00296     for (ii = 0; ii < lp_ncols; ++ii) {
00297         std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00298             glp_get_col_prim(lp, ii + 1) << std::setw(12) << qq[ii] << std::endl;
00299     }
00300     std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00301         obj_value << std::endl;
00302     #endif
00303
00304     if (copy) {
00305         for(ii = 0; ii < lp_ncols; ++ii) {
00306             qq[ii] = glp_get_col_prim(lp, ii + 1);
00307         }
00308         // Preserve the bottom values of qq.
00309     }
00310
00311     x1 = mtk::BLASAdapter::RealNRM2(err, lp_ncols);
00312
00313 } else {
00314     x1 = std::numeric_limits<mtk::Real>::infinity();
00315 }
00316
00317 glp_delete_prob (lp);
00318 glp_free_env ();
00319
00320 delete [] ia;
00321 delete [] ja;
00322 delete [] ar;
00323 delete [] objective;
00324 delete [] rhs;
00325 delete [] err;
00326
00327 return x1;
00328 }

```

## 17.65 src/mtk\_grad\_1d.cc File Reference

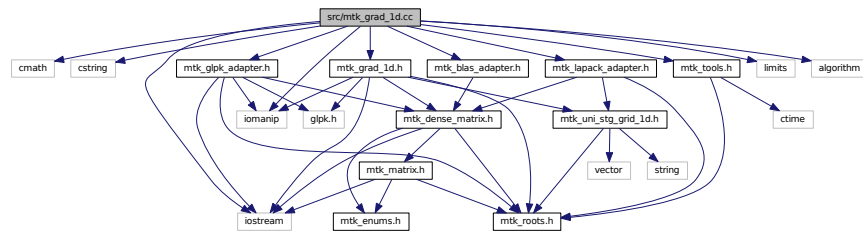
Implements the class Grad1D.

```

#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)`

### 17.65.1 Detailed Description

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

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

**Todo** Overload ostream operator as in [mtk::Lap1D](#).

**Todo** Implement creation of ■ w. [mtk::BLASAdapter](#).

Definition in file [mtk\\_grad\\_1d.cc](#).

## 17.66 mtk\_grad\_1d.cc

```

00001
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.
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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
00102
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
00201     bool abort_construction = ComputeStencilInteriorGrid();
00202
00203     #ifdef MTK_PERFORM_PREVENTIONS
00204     if (!abort_construction) {
00205         std::cerr << "Could NOT complete stage 1." << std::endl;
00206         std::cerr << "Exiting..." << std::endl;
00207         return false;
00208     }
00209     #endif
00210
00211     // At this point, we already have the values for the interior stencil stored
00212     // in the coeffs_interior_ array.
00213
00214     dim_null_ = order_accuracy_/2 - 1;
00215
00216     num_bndy_approxs_ = dim_null_ + 1;
00217
00218     #ifdef MTK_PRECISION_DOUBLE
00219     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00220     #else
00221     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00222     #endif
00223
00224     // For this we will follow recommendations given in:
00225     //
00226     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00227     //
00228     // We will compute the QR Factorization of the transpose, as in the
00229     // following (MATLAB) pseudo-code:
00230     //
00231     // [Q,R] = qr(V'); % Full QR as defined in
00232     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00233     //
00234     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00235     //
00236     // However, given the nature of the Vandermonde matrices we've just
00237     // computed, they all posses the same null-space. Therefore, we impose the
00238     // convention of computing the null-space of the first Vandermonde matrix
00239     // (west boundary).
00240
00241     // In the case of the gradient, the first Vandermonde system has a unique
00242     // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00243     // matrix used to assemble said system, will have an empty null-space.
00244
00245     // Therefore, we only compute a rational basis for the case of order higher
00246     // than second.
00247
00248     if (dim_null_ > 0) {
00249         abort_construction = ComputeRationalBasisNullSpace();
00250
00251         #ifdef MTK_PERFORM_PREVENTIONS
00252         if (!abort_construction) {
00253             std::cerr << "Could NOT complete stage 2.1." << std::endl;
00254         }
00255     }
00256 }

```

```

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     abort_construction = ComputeStencilBoundaryGrid();
00289
00290     #ifdef MTK_PERFORM_PREVENTIONS
00291     if (!abort_construction) {
00292         std::cerr << "Could NOT complete stage 2.4." << std::endl;
00293         std::cerr << "Exiting..." << std::endl;
00294         return false;
00295     }
00296     #endif
00297 }
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
00380
00381     auto ee_index = 0;
00382     for (auto ii = 0; ii < num_extra_rows; ii++) {
00383         auto cc = 0;
00384         for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00385             if(cc >= elements_per_row) {
00386                 out.SetValue(ii, jj, mtk::kZero);
00387             } else {
00388                 out.SetValue(ii,jj,
00389                             gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00390                 cc++;
00391             }
00392         }
00393     }
00394 }
00395
00396
00397     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00398         auto jj = ii - num_extra_rows + 1;
00399         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00400             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00401         }
00402     }
00403 }
00404
00405
00406     ee_index = 0;
00407     for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00408         auto cc = 0;
00409         for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00410             if(cc >= elements_per_row) {
00411                 out.SetValue(ii,jj,mtk::kZero);
00412             } else {
00413                 out.SetValue(ii,jj,
00414                             -gradient_[2*order_accuracy_ + 1 +
00415 ee_index++]*inv_delta_x);
00416                 cc++;
00417             }
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
00445     auto ee_index = 0;
00446     for (auto ii = 0; ii < num_extra_rows; ii++) {
00447         auto cc = 0;
00448         for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00449             if(cc >= elements_per_row) {
00450                 out.SetValue(ii, jj, mtk::kZero);
00451             } else {
00452                 out.SetValue(ii, jj,
00453                     gradient_[2*order_accuracy_ + 1 + ee_index++] * inv_delta_x);
00454                 cc++;
00455             }
00456         }
00457     }
00458
00459     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00460         auto jj = ii - num_extra_rows + 1;
00461         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00462             out.SetValue(ii, jj, coeffs_interior_[cc] * inv_delta_x);
00463         }
00464     }
00465
00466     ee_index = 0;
00467     for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00468         auto cc = 0;
00469         for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00470             if(cc >= elements_per_row) {
00471                 out.SetValue(ii, jj, mtk::kZero);
00472             } else {
00473                 out.SetValue(ii, jj,
00474                     -gradient_[2*order_accuracy_ + 1 + ee_index++] * inv_delta_x);
00475                 cc++;
00476             }
00477         }
00478     }
00479
00480     return out;
00481 }
00482
00483 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix
00484 (
00485     int num_cells_x) const {
00486
00487     int nn{num_cells_x}; // Number of cells on the grid.
00488
00489     #ifdef MTK_PERFORM_PREVENTIONS
00490     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00491     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00492     #endif
00493
00494     int gg_num_rows = nn + 1;
00495     int gg_num_cols = nn + 2;
00496     int elements_per_row = num_bndy_coeffs_;
00497     int num_extra_rows = order_accuracy_/2;
00498
00499     // Output matrix featuring sizes for gradient operators.
00500     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00501
00502     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
00523     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00524         auto jj = ii - num_extra_rows + 1;
00525         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00526             out.SetValue(ii, jj, coeffs_interior_[cc]);
00527         }
00528     }
00529
00530     ee_index = 0;
00531     for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00532         auto cc = 0;
00533         for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00534             if(cc >= elements_per_row) {
00535                 out.SetValue(ii, jj, mtk::kZero);
00536             } else {
00537                 out.SetValue(ii, jj,
00538                     -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00539                 cc++;
00540             }
00541         }
00542     }
00543
00544     return out;
00545 }
00546
00547 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00548
00549     mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00550
00551     try {
00552         pp = new mtk::Real[order_accuracy_];
00553     } catch (std::bad_alloc &memory_allocation_exception) {
00554         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00555             std::endl;
00556         std::cerr << memory_allocation_exception.what() << std::endl;
00557     }
00558     memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00559
00560     #ifdef MTK_PRECISION_DOUBLE
00561     pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00562     #else
00563     pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00564     #endif
00565
00566     for (auto ii = 1; ii < order_accuracy_; ++ii) {
00567         pp[ii] = pp[ii - 1] + mtk::kOne;
00568     }
00569
00570     #if MTK_VERBOSE_LEVEL > 3
00571     std::cout << "pp =" << std::endl;
00572     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00573         std::cout << std::setw(12) << pp[ii];
00574     }
00575     std::cout << std::endl << std::endl;
00576     #endif
00577
00578     bool transpose{false};
00579
00580     mtk::DenseMatrix vander_matrix(pp, order_accuracy_, order_accuracy_, transpose);
00581
00582     #if MTK_VERBOSE_LEVEL > 4
00583     std::cout << "vander_matrix =" << std::endl;
00584     std::cout << vander_matrix << std::endl << std::endl;
00585     #endif
00586
00587
00588
00589
00590
00591
00592
00593
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
00617
00618     int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00619         coeffs_interior_)};
00620
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
00650
00651     mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00652
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
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
00692
00693     mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
00694 (aa_west_t));
00695
00696     #if MTK_VERBOSE_LEVEL > 3
00697     std::cout << "qq_t = " << std::endl;
00698     std::cout << qq_t << std::endl;
00699     #endif
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 scalars.
00780 // An example of the system to solve, for k = 8, is:
00781 //
00782 // subk*scalars = iden or
00783 //
00784 // | 0.386018 -0.0339244 -0.129478 | | 1 0 0 |
00785 // | -0.119774 0.0199423 0.0558632 |*scalars = | 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 scalars... 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 scalars:" << 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
00833     mtk::Real *gg{}; // Generator vector for the first approximation.
00834
00835     try {
00836         gg = new mtk::Real[num_bndy_coeffs_];
00837     } catch (std::bad_alloc &memory_allocation_exception) {
00838         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00839             std::endl;
00840         std::cerr << memory_allocation_exception.what() << std::endl;
00841     }
00842     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
00875 for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00876
00877     // Re-check new generator vector for every iteration except for the first.
00878     #if MTK_VERBOSE_LEVEL > 3
00879     if (ll > 0) {
00880         std::cout << "gg_" << ll << " =" << std::endl;
00881         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00882             std::cout << std::setw(12) << gg[ii];
00883         }
00884         std::cout << std::endl << std::endl;
00885     }
00886     #endif
00887
00888     bool transpose{false};
00889
00890     mtk::DenseMatrix aa(gg,
00891         num_bndy_coeffs_, order_accuracy_ + 1,
00892         transpose);
00893
00894     #if MTK_VERBOSE_LEVEL > 4
00895     std::cout << "aa_" << ll << " =" << std::endl;
00896     std::cout << aa << std::endl;
00897     #endif
00898
00899     mtk::Real *ob{};
00900
00901     auto ob_ld = num_bndy_coeffs_;
00902
00903     try {
00904         ob = new mtk::Real[ob_ld];
00905     } catch (std::bad_alloc &memory_allocation_exception) {
00906         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00907         std::endl;
00908         std::cerr << memory_allocation_exception.what() << std::endl;
00909     }
00910     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00911
00912     ob[1] = mtk::kOne;
00913
00914     #if MTK_VERBOSE_LEVEL > 3
00915     std::cout << "ob =" << std::endl << std::endl;
00916     for (auto ii = 0; ii < ob_ld; ++ii) {
00917         std::cout << std::setw(12) << ob[ii] << std::endl;
00918     }
00919     std::cout << std::endl;
00920     #endif
00921
00922
00923
00924
00925
00926
00927
00928

```

```

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
00954     // This implies a DAXPY operation. However, we must construct the arguments
00955     // for this operation.
00956
00957     // Save them into the ob_bottom array:
00958
00959     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00960
00961     try {
00962         ob_bottom = new mtk::Real[dim_null_];
00963     } catch (std::bad_alloc &memory_allocation_exception) {
00964         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
std::endl;
00965         std::cerr << memory_allocation_exception.what() << std::endl;
00966     }
00967     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00968
00969     for (auto ii = 0; ii < dim_null_; ++ii) {
00970         ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00971     }
00972
00973     #if MTK_VERBOSE_LEVEL > 3
00974     std::cout << "ob_bottom =" << std::endl;
00975     for (auto ii = 0; ii < dim_null_; ++ii) {
00976         std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00977     }
00978     std::cout << std::endl;
00979     #endif
00980
00981     // We must computed an scaled ob, sob, using the scaled null-space in
00982     // rat_basis_null_space_.
00983     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00984     // or:
00985     //      ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00986     // thus:
00987     //      Y =      a*A      *x      +      b*Y (DAXPY).
00988
00989     #if MTK_VERBOSE_LEVEL > 4
00990     std::cout << "Rational basis for the null-space:" << std::endl;
00991     std::cout << rat_basis_null_space_ << std::endl;
00992     #endif
00993
00994     mtk::Real alpha{-mtk::kOne};
00995     mtk::Real beta{mtk::kOne};
00996
00997     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
ob_bottom, beta, ob);
00998
00999     #if MTK_VERBOSE_LEVEL > 3
01000     std::cout << "scaled ob:" << std::endl;
01001     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01002         std::cout << std::setw(12) << ob[ii] << std::endl;
01003     }
01004     std::cout << std::endl;
01005     #endif
01006
01007     // 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_ + 11] = 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 (11 = 0; 11 < dim_null; 11++);
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
01057     // Assemble the pi matrix using:
01058     // 1. The collection of scaled preliminary approximations.
01059     // 2. The collection of coefficients approximating at the interior.
01060     // 3. The scaled basis for the null-space.
01061
01062     // 1.1. Process array of scaled preliminary approximations.
01063
01064     // These are queued in scaled_solutions. Each one of these, will be a column
01065     // of the pi matrix:
01066     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01067         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01068             pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
01069                 prem_apps_[ii*num_bndy_approxs_ + jj];
01070         }
01071     }
01072
01073     // 1.2. Add columns from known stencil approximating at the interior.
01074
01075     // However, these must be padded by zeros, according to their position in the
01076     // final pi matrix:
01077     auto mm = 1;
01078     for (auto jj = num_bndy_approxs_; jj < order_accuracy_; ++jj) {
01079         for (auto ii = 0; ii < order_accuracy_; ++ii) {
01080             auto de = (ii + mm)*(2*(num_bndy_approxs_ - 1) +
01081                 (order_accuracy_/2 + 1)) + jj;
01082             pi.data()[de] = coeffs_interior_[ii];
01083         }
01084         ++mm;
01085     }
01086
01087     rat_basis_null_space_.OrderColMajor();
01088
01089     #if MTK_VERBOSE_LEVEL > 4
01090     std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01091     std::cout << rat_basis_null_space_ << std::endl;
01092     #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
01121 // This imposes the mimetic condition.
01122
01123 mtk::Real *hh{}; // Right-hand side to compute weights in the C{R,B}SA.
01124
01125 try {
01126     hh = new mtk::Real[num_bndy_coeffs_];
01127 } catch (std::bad_alloc &memory_allocation_exception) {
01128     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01129         std::endl;
01130     std::cerr << memory_allocation_exception.what() << std::endl;
01131 }
01132 memset(hh, mtk::kZero, sizeof(hh[0]) * num_bndy_coeffs_);
01133
01134 hh[0] = -mtk::kOne;
01135 for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01136     auto aux_xx = mtk::kZero;
01137     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01138         aux_xx += coeffs_interior_[jj];
01139     }
01140     hh[ii] = -mtk::kOne * aux_xx;
01141 }
01142
01143 // That is, we construct a system, to solve for the weights.
01144
01145 // Once again we face the challenge of solving with LAPACK. However, for the
01146 // CRSA, this matrix PI is over-determined, since it has more rows than
01147 // unknowns. However, according to the theory, the solution to this system is
01148 // unique. We will use dgels_.
01149
01150 try {
01151     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01152 } catch (std::bad_alloc &memory_allocation_exception) {
01153     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01154         std::endl;
01155     std::cerr << memory_allocation_exception.what() << std::endl;
01156 }
01157 memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0]) * num_bndy_coeffs_);
01158
01159 int weights_ld{pi.num_cols() + 1};
01160
01161 // Preserve hh.
01162 std::copy(hh, hh + weights_ld, weights_cbs_);
01163
01164 pi.Transpose();
01165
01166 int info{
01167     mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01168         weights_cbs_, weights_ld)
01169 };
01170
01171 #ifdef MTK_PERFORM_PREVENTIONS
01172 if (!info) {
01173     std::cout << "System successfully solved!" << std::endl << std::endl;
01174 }

```

```

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
01213 if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01214
01215     int minrow{std::numeric_limits<int>::infinity()};
01216
01217     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
01218         order_accuracy_)};
01219     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01220
01221     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01222
01223 // 6.1. Insert preliminary approximations to first set of columns.
01224
01225     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01226         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01227             phi.data()[ii*(order_accuracy_ + 1) + jj] =
01228                 prem_apps_[ii*num_bndy_approxs_ + jj];
01229         }
01230     }
01231
01232 // 6.2. Skip a column and negate preliminary approximations.
01233
01234     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01235         for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01236             auto de = (ii + order_accuracy_ - num_bndy_approxs_ + jj*order_accuracy_);
01237             auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01238             phi.data()[de] = -pre_apps_[og];
01239         }
01240     }
01241
01242 // 6.3. Flip negative columns up-down.
01243
01244     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01245         for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01246             auto aux = phi.data()[ii*order_accuracy_ + jj];
01247             phi.data()[ii*order_accuracy_ + jj] =
01248                 phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj];
01249             phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01250         }
01251     }
01252
01253 // 6.4. Insert stencil.
01254
01255     auto mm = 0;
01256     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
01275 mtk::Real *lamed{}; // Used to build big lambda.
01276
01277 try {
01278     lamed = new mtk::Real[num_bndy_approxs_ - 1];
01279 } catch (std::bad_alloc &memory_allocation_exception) {
01280     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01281         std::endl;
01282     std::cerr << memory_allocation_exception.what() << std::endl;
01283 }
01284 memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01285
01286 for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01287     lamed[ii] = hh[ii + order_accuracy_ + 1];
01288 }
01289
01290 #if MTK_VERBOSE_LEVEL > 3
01291 std::cout << "lamed =" << std::endl;
01292 for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01293     std::cout << std::setw(12) << lamed[ii] << std::endl;
01294 }
01295 std::cout << std::endl;
01296 #endif
01297
01298 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01299     mtk::Real temp = mtk::kZero;
01300     for (auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01301         temp = temp +
01302             lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01303     }
01304     hh[ii] = hh[ii] - temp;
01305 }
01306
01307 #if MTK_VERBOSE_LEVEL > 3
01308 std::cout << "big_lambda =" << std::endl;
01309 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01310     std::cout << std::setw(12) << hh[ii] << std::endl;
01311 }
01312 std::cout << std::endl;
01313 #endif
01314
01315 int copy_result{}; // Should I replace the solution... not for now.
01316
01317 mtk::Real normerr_; // Norm of the error for the solution on each row.
01318
01319 for (auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01320     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01321 data(),
01322                                     order_accuracy_ + 1,
01323                                     order_accuracy_,
01324                                     order_accuracy_,
01325                                     hh,
01326                                     weights_cbs_,
01327                                     row_,
01328                                     mimetic_threshold_,
01329                                     copy_result);
01330
01331     mtk::Real aux{normerr_/norm};
01332
01333     #if MTK_VERBOSE_LEVEL > 2
01334     std::cout << "Relative norm: " << aux << " " << std::endl;
01335     std::cout << std::endl;
01336     #endif
01337
01338     if (aux < minnorm) {
01339         minnorm = aux;
01340     }
01341 }

```

```

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
01355 // After we know which row yields the smallest relative norm that row is
01356 // chosen to be the objective function and the result of the optimizer is
01357 // chosen to be the new weights_.
01358
01359 #if MTK_VERBOSE_LEVEL > 2
01360 std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01361 minrow_ + 1 << std::endl;
01362 std::cout << std::endl;
01363 #endif
01364
01365 copy_result = 1;
01366 normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01367 data(),
01368                                     order_accuracy_ + 1,
01369                                     order_accuracy_,
01370                                     order_accuracy_,
01371                                     hh,
01372                                     weights_cbs_,
01373                                     minrow_,
01374                                     mimetic_threshold_,
01375                                     copy_result);
01376
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
01403 mtk::Real *lambda{}; // Collection of bottom values from weights_.
01404
01405 try {
01406     lambda = new mtk::Real[dim_null_];
01407 } catch (std::bad_alloc &memory_allocation_exception) {
01408     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01409     std::endl;
01410     std::cerr << memory_allocation_exception.what() << std::endl;
01411 }
01412
01413 memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01414
01415 for (auto ii = 0; ii < dim_null_; ++ii) {
01416     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01417 }
01418
01419 #if MTK_VERBOSE_LEVEL > 3
01420 std::cout << "lambda =" << std::endl;
01421 for (auto ii = 0; ii < dim_null_; ++ii) {
01422     std::cout << std::setw(12) << lambda[ii] << std::endl;

```

```

01424     }
01425     std::cout << std::endl;
01426 #endif
01427
01428
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
01453
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 }

```

## 17.67 src/mtk\_grad\_2d.cc File Reference

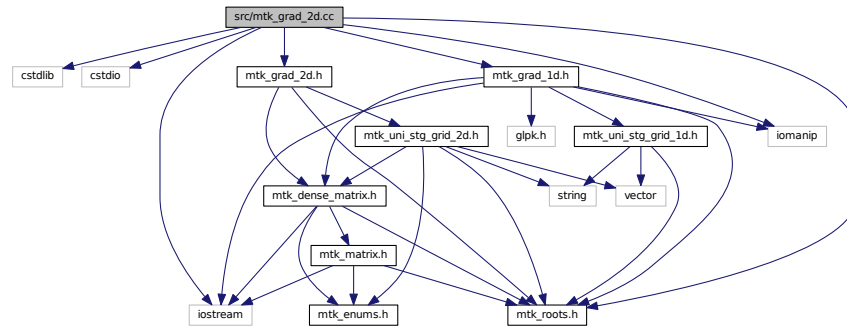
Implements the class Grad2D.

```

#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:



### 17.67.1 Detailed Description

This class implements a 2D 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\\_2d.cc](#).

## 17.68 mtk\_grad\_2d.cc

```

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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:
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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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```

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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,
                                int order_accuracy,
                                mtk::Real mimetic_threshold) {
00078
00079
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 }

```

## 17.69 src/mtk\_interp\_1d.cc File Reference

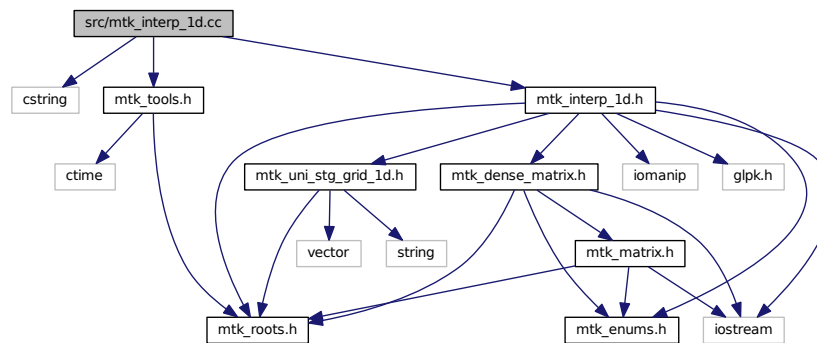
Includes the implementation of the class Interp1D.

```

#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)`

## 17.69.1 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](#).

## 17.70 mtk\_interp\_1d.cc

```

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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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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
00068
00069     stream << "coeffs_interior_[1:" << in.order_accuracy_ << "]" = ";
00070     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
00112     try {
00113         coeffs_interior_ = new mtk::Real[order_accuracy_];
00114     } catch (std::bad_alloc &memory_allocation_exception) {
00115         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00116             std::endl;
00117         std::cerr << memory_allocation_exception.what() << std::endl;
00118     }
00119     memset(coeffs_interior_,
00120            mtk::kZero,
00121            sizeof(coeffs_interior_[0])*order_accuracy_);
00122
00123     for (int ii = 0; ii < order_accuracy_; ++ii) {
00124         coeffs_interior_[ii] = mtk::kOne;
00125     }
00126
00127     return true;
00128 }
00129
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 out.SetValue(0, 0, mtk::kOne);
00163
00164
00166 for (auto ii = 1; ii < gg_num_rows - 1; ++ii) {
00167     for (auto jj = ii; jj < order_accuracy_ + ii; ++jj) {
00168         out.SetValue(ii, jj, mtk::kOne/order_accuracy_);
00169     }
00170 }
00171 }
00172
00174
00175 out.SetValue(gg_num_rows - 1, gg_num_cols - 1, mtk::kOne);
00176
00177 return out;
00178 }

```

## 17.71 src/mtk\_lap\_1d.cc File Reference

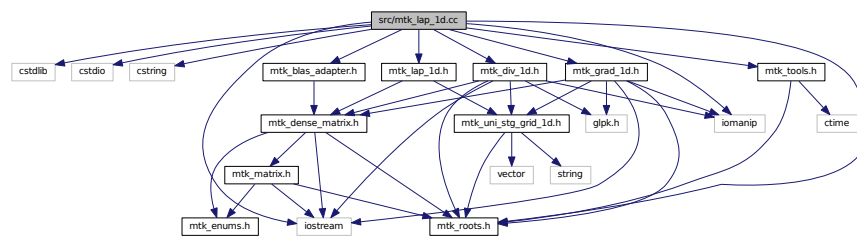
Includes the implementation of the class Lap1D.

```

#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)`

### 17.71.1 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](#).

## 17.72 mtk\_lap\_1d.cc

```

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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 #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_ld.h"
00068 #include "mtk_div_ld.h"
00069 #include "mtk_lap_ld.h"
00070
00071 namespace mtk {
00072
00073 std::ostream& operator <<(std::ostream &stream, mtk::Lap1D &in) {
00074
00075     stream << "laplacian_[0] = " << in.laplacian_[0] << std::endl << std::endl;
00076
00077     stream << "laplacian_[1:" << 2*in.order_accuracy_ - 1 << "]" = " <<
00078         std::endl << std::endl;
00079     for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00080         stream << std::setw(13) << in.laplacian_[ii] << " ";
00081     }
00082     stream << std::endl << std::endl;
00083
00084     auto offset = 1 + (2*in.order_accuracy_ - 1);
00085
00086     stream << "laplacian_[" << offset << ":" << offset +
00087         (in.order_accuracy_ - 1)*(2*in.order_accuracy_ - 1) << "]" = " <<
00088         std::endl << std::endl;
00089     for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00090         for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00091             stream << std::setw(13) <<
00092                 in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00093         }
00094         stream << std::endl;
00095     }
00096     return stream;
00097 }
00098
00099 mtk::Lap1D::Lap1D():
00100     order_accuracy_(mtk::kDefaultOrderAccuracy),
00101     laplacian_length_(),
00102     delta_(mtk::kZero),
00103     mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00104
00105 mtk::Lap1D::~Lap1D() {
00106     delete [] laplacian_;
00107     laplacian_ = nullptr;
00108 }
00109
00110 int mtk::Lap1D::order_accuracy() const {
00111     return order_accuracy_;
00112 }
00113
00114 mtk::Real mtk::Lap1D::mimetic_threshold() const {
00115     return mimetic_threshold_;
00116 }
00117
00118 mtk::Real mtk::Lap1D::delta() const {
00119     return delta_;
00120 }
00121
00122 bool mtk::Lap1D::ConstructLap1D(int order_accuracy,
00123     mtk::Real mimetic_threshold) {
00124
00125     #ifdef MTK_PERFORM_PREVENTIONS
00126     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00127     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00128     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00129         __FILE__, __LINE__, __func__);
00130
00131     if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00132         std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00133     }
00134 }

```

```

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
00155     mtk::Grad1D grad; // Mimetic gradient.
00156
00157     bool info = grad.ConstructGrad1D(order_accuracy_, mimetic_threshold_);
00158
00159     #ifdef MTK_PERFORM_PREVENTIONS
00160     if (!info) {
00161         std::cerr << "Mimetic grad could not be built." << std::endl;
00162         return false;
00163     }
00164     #endif
00165
00166     mtk::Div1D div; // Mimetic divergence.
00167
00168     info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00169
00170     #ifdef MTK_PERFORM_PREVENTIONS
00171     if (!info) {
00172         std::cerr << "Mimetic div could not be built." << std::endl;
00173         return false;
00174     }
00175     #endif
00176
00177     // Since these are mimetic operator, we must multiply the matrices arising
00178     // from both the divergence and the Laplacian, in order to get the
00179     // approximating coefficients for the Laplacian operator.
00180
00181     // However, we must choose a grid that implied a step size of 1, so to get
00182     // the approximating coefficients, without being affected from the
00183     // normalization with respect to the grid (dimensionless).
00184
00185     // Also, the grid must be of the minimum size to support the requested order
00186     // of accuracy. We must please the divergence for this!
00187
00188     mtk::UniStgGrid1D aux(mtk::kZero,
00189                          (mtk::Real) 3*order_accuracy_ - 1,
00190                          3*order_accuracy_ - 1);
00191
00192     #if MTK_VERBOSE_LEVEL > 2
00193     std::cout << "aux =" << std::endl;
00194     std::cout << aux << std::endl;
00195     std::cout << "aux.delta_x() = " << aux.delta_x() << std::endl;
00196     std::cout << std::endl;
00197     #endif
00198
00199     mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00200
00201     #if MTK_VERBOSE_LEVEL > 4
00202     std::cout << "grad_m =" << std::endl;
00203     std::cout << grad_m << std::endl;
00204     #endif
00205
00206     mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00207
00208     #if MTK_VERBOSE_LEVEL > 4
00209     std::cout << "div_m =" << std::endl;
00210     std::cout << div_m << std::endl;
00211     #endif
00212
00213     mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00214
00215     lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00216
00217     #if MTK_VERBOSE_LEVEL > 4
00218     std::cout << "lap =" << std::endl;
00219     std::cout << lap << std::endl;
00220     #endif
00221
00222
00223
00224
00225
00226
00227
00228
00229
00230
00231
00232
00233
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 laplacian_[0] = order_accuracy_;
00262
00265 for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00266     laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00267 }
00269
00271 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::LaplD::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
00301     dx^2.
00302
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 }

```

## 17.73 src/mtk\_lap\_2d.cc File Reference

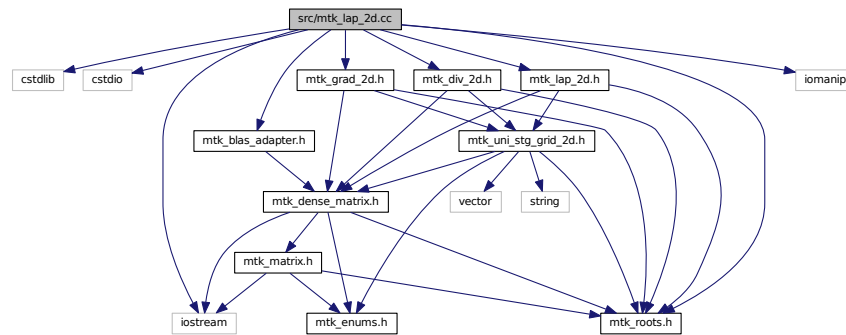
Includes the implementation of the class Lap2D.

```

#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`:



### 17.73.1 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](#).

## 17.74 mtk\_lap\_2d.cc

```

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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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```

```

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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_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 }

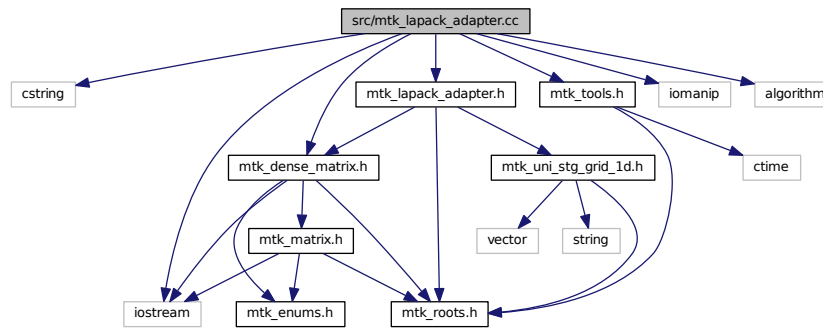
```

## 17.75 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.*

### 17.75.1 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](#).

## 17.76 mtk\_lapack\_adapter.cc

```

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00029 and a copy of the modified files should be reported once modifications are
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,
    mtk::Real *rhs) {
00431
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,
    mtk::DenseMatrix &bb) {
00466
00467     int nrhs{bb.num_rows()}; // Number of right-hand sides.
00468
00469     #ifdef MTK_PERFORM_PREVENTIONS
00470     mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00471     #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(
00518     mtk::DenseMatrix &mm,
00519                                     mtk::UniStgGrid1D &rhs) {
00520
00521     int nrhs{1}; // Number of right-hand sides.
00522
00523     int *ipiv{};                // Array for pivoting information.
00524     int info{};                // Status of the solution.
00525     int mm_rank{mm.num_rows()}; // Rank of the matrix.
00526
00527     try {
00528         ipiv = new int[mm_rank];
00529     } catch (std::bad_alloc &memory_allocation_exception) {
00530         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00531             std::endl;
00532         std::cerr << memory_allocation_exception.what() << std::endl;
00533     }
00534     memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00535
00536     int ldbb = mm_rank;
00537     int mm_ld = mm_rank;
00538
00539     mm.OrderColMajor();
00540
00541     #ifdef MTK_PRECISION_DOUBLE
00542     dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00543         rhs.discrete_field(), &ldbb, &info);
00544     #else
00545     fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00546         rhs.discrete_field(), &ldbb, &info);
00547     #endif
00548
00549     mm.OrderRowMajor();
00550
00551     delete [] ipiv;
00552
00553     return info;

```



```

00553 }
00554
00555 mtk::DenseMatrix mtk::LAPACKAdapter::QRFactorDenseMatrix
(mtk::DenseMatrix &aa) {
00556
00557     mtk::Real *work{}; // Working array.
00558     mtk::Real *tau{}; // Array for the Householder scalars.
00559
00560     // Prepare to factorize: allocate and inquire for the value of lwork.
00561     try {
00562         work = new mtk::Real[1];
00563     } catch (std::bad_alloc &memory_allocation_exception) {
00564         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00565             std::endl;
00566         std::cerr << memory_allocation_exception.what() << std::endl;
00567     }
00568     memset(work, mtk::kZero, sizeof(aa.data()[0])*1);
00569
00570     int lwork{-1};
00571     int info{};
00572
00573     int aa_num_cols = aa.num_cols();
00574     int aaT_num_rows = aa.num_cols();
00575     int aaT_num_cols = aa.num_rows();
00576
00577     #if MTK_VERBOSE_LEVEL > 12
00578     std::cout << "Input matrix BEFORE QR factorization:" << std::endl;
00579     std::cout << aa << std::endl;
00580     #endif
00581
00582     #ifdef MTK_PRECISION_DOUBLE
00583     dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00584         tau,
00585         work, &lwork, &info);
00586     #else
00587     fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00588         tau,
00589         work, &lwork, &info);
00590     #endif
00591
00592     if (info == 0) {
00593         lwork = (int) work[0];
00594     } else {
00595         std::cerr << "Could not get value for lwork on line " << __LINE__ - 5 <<
00596             std::endl;
00597         std::cerr << "Exiting..." << std::endl;
00598     }
00599
00600     #if MTK_VERBOSE_LEVEL > 10
00601     std::cout << "lwork = " << std::endl << std::setw(12) << lwork << std::endl
00602         << std::endl;
00603     #endif
00604
00605     delete [] work;
00606     work = nullptr;
00607
00608     // Once we know lwork, we can actually invoke the factorization:
00609     try {
00610         work = new mtk::Real [lwork];
00611     } catch (std::bad_alloc &memory_allocation_exception) {
00612         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00613             std::endl;
00614         std::cerr << memory_allocation_exception.what() << std::endl;
00615     }
00616     memset(work, mtk::kZero, sizeof(work[0])*lwork);
00617
00618     int ltau = std::min(aaT_num_rows, aaT_num_cols);
00619
00620     try {
00621         tau = new mtk::Real [ltau];
00622     } catch (std::bad_alloc &memory_allocation_exception) {
00623         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00624             std::endl;
00625         std::cerr << memory_allocation_exception.what() << std::endl;
00626     }
00627     memset(tau, mtk::kZero, sizeof(0.0)*ltau);
00628
00629     #ifdef MTK_PRECISION_DOUBLE
00630     dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00631         tau, work, &lwork, &info);
00632     #else

```

```

00633 fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00634         tau, work, &lwork, &info);
00635 #endif
00636
00637 #ifdef MTK_PERFORM_PREVENTIONS
00638 if (!info) {
00639     std::cout << "QR factorization completed!" << std::endl << std::endl;
00640 } else {
00641     std::cerr << "Error solving system! info = " << info << std::endl;
00642     std::cerr << "Exiting..." << std::endl;
00643 }
00644 #endif
00645
00646 #if MTK_VERBOSE_LEVEL > 12
00647 std::cout << "Input matrix AFTER QR factorization:" << std::endl;
00648 std::cout << aa << std::endl;
00649 #endif
00650
00651 // We now generate the real matrix Q with orthonormal columns. This has to
00652 // be done separately since the actual output of dgeqrf_ (AA_) represents
00653 // the orthogonal matrix Q as a product of min(aa_num_rows,aa_num_cols)
00654 // elementary Householder reflectors. Notice that we must re-inquire the new
00655 // value for lwork that is used.
00656
00657 bool padded{false};
00658
00659 bool transpose{false};
00660
00661 mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00662
00663 #if MTK_VERBOSE_LEVEL > 12
00664 std::cout << "Initialized QQ_T: " << std::endl;
00665 std::cout << QQ_ << std::endl;
00666 #endif
00667
00668 // Assemble the QQ_ matrix:
00669 lwork = -1;
00670
00671 delete[] work;
00672 work = nullptr;
00673
00674 try {
00675     work = new mtk::Real[l];
00676 } catch (std::bad_alloc &memory_allocation_exception) {
00677     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00678         std::endl;
00679     std::cerr << memory_allocation_exception.what() <<
00680         std::endl;
00681 }
00682 memset(work, mtk::kZero, sizeof(work[0])*l);
00683
00684 char side_{'L'};
00685 char trans_{'N'};
00686
00687 int aux = QQ_.num_rows();
00688
00689 #ifdef MTK_PRECISION_DOUBLE
00690 dormqr_(&side_, &trans_,
00691         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00692         QQ_.data(), &aux, work, &lwork, &info);
00693 #else
00694 formqr_(&side_, &trans_,
00695         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00696         QQ_.data(), &aux, work, &lwork, &info);
00697 #endif
00698
00699 if (info == 0) {
00700     lwork = (int) work[0];
00701 } else {
00702     std::cerr << "Could not get lwork on line " << __LINE__ - 5 << std::endl;
00703     std::cerr << "Exiting..." << std::endl;
00704 }
00705
00706 #if MTK_VERBOSE_LEVEL > 10
00707 std::cout << "lwork = " << std::endl << std::setw(12) << lwork <<
00708     std::endl << std::endl;
00709 #endif
00710
00711 delete[] work;
00712 work = nullptr;
00713

```

```

00714     try {
00715         work = new mtk::Real[lwork];
00716     } catch (std::bad_alloc &memory_allocation_exception) {
00717         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00718             std::endl;
00719         std::cerr << memory_allocation_exception.what() << std::endl;
00720     }
00721     memset(work, mtk::kZero, sizeof(work[0])*lwork);
00722
00723     #ifdef MTK_PRECISION_DOUBLE
00724     dormqr_(&side_, &trans_,
00725         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00726         QQ_.data(), &aux, work, &lwork, &info);
00727     #else
00728     formqr_(&side_, &trans_,
00729         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00730         QQ_.data(), &aux, work, &lwork, &info);
00731     #endif
00732
00733     #ifdef MTK_PERFORM_PREVENTIONS
00734     if (!info) {
00735         std::cout << "Q matrix successfully assembled!" << std::endl << std::endl;
00736     } else {
00737         std::cerr << "Something went wrong solving system! info = " << info <<
00738             std::endl;
00739         std::cerr << "Exiting..." << std::endl;
00740     }
00741     #endif
00742
00743     delete[] work;
00744     work = nullptr;
00745
00746     delete[] tau;
00747     tau = nullptr;
00748
00749     return QQ_;
00750 }
00751
00752 int mtk::LAPACKAdapter::SolveRectangularDenseSystem(const
mtk::DenseMatrix &aa,
                                mtk::Real *ob_,
                                int ob_ld_) {
00753
00754     // We first invoke the solver to query for the value of lwork. For this,
00755     // we must at least allocate enough space to allow access to WORK(1), or
00756     // work[0]:
00757
00758     // If LWORK = -1, then a workspace query is assumed; the routine only
00759     // calculates the optimal size of the WORK array, returns this value as
00760     // the first entry of the WORK array, and no error message related to
00761     // LWORK is issued by XERBLA.
00762
00763     mtk::Real *work{}; // Work array.
00764
00765     try {
00766         work = new mtk::Real[l];
00767     } catch (std::bad_alloc &memory_allocation_exception) {
00768         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00769             std::endl;
00770         std::cerr << memory_allocation_exception.what() << std::endl;
00771     }
00772     memset(work, mtk::kZero, sizeof(work[0])*l);
00773
00774     char trans_{'N'};
00775     int nrhs_{1};
00776     int info{0};
00777     int lwork{-1};
00778
00779     int AA_num_rows_ = aa.num_cols();
00780     int AA_num_cols_ = aa.num_rows();
00781     int AA_ld_ = std::max(1, aa.num_cols());
00782
00783     #ifdef MTK_PRECISION_DOUBLE
00784     dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00785         ob_, &ob_ld_,
00786         work, &lwork, &info);
00787     #else
00788     sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00789         ob_, &ob_ld_,
00790         work, &lwork, &info);
00791     #endif
00792
00793

```

```

00794
00795     if (info == 0) {
00796         lwork = (int) work[0];
00797     } else {
00798         std::cerr << "Could not get value for lwork on line " << __LINE__ - 2 <<
00799             std::endl;
00800         std::cerr << "Exiting..." << std::endl;
00801         return info;
00802     }
00803
00804     #if MTK_VERBOSE_LEVEL > 10
00805     std::cout << "lwork = " << std::endl << std::setw(12)<< lwork <<
00806         std::endl << std::endl;
00807     #endif
00808
00809     // We then use lwork's new value to create the work array:
00810     delete[] work;
00811     work = nullptr;
00812
00813     try {
00814         work = new mtk::Real[lwork];
00815     } catch (std::bad_alloc &memory_allocation_exception) {
00816         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00817         std::cerr << memory_allocation_exception.what() << std::endl;
00818     }
00819     memset(work, 0.0, sizeof(work[0])*lwork);
00820
00821     // We now invoke the solver again:
00822     #ifdef MTK_PRECISION_DOUBLE
00823     dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00824         ob_, &ob_ld_,
00825         work, &lwork, &info);
00826     #else
00827     sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00828         ob_, &ob_ld_,
00829         work, &lwork, &info);
00830     #endif
00831
00832     delete [] work;
00833     work = nullptr;
00834
00835     return info;
00836 }

```

## 17.77 src/mtk\_matrix.cc File Reference

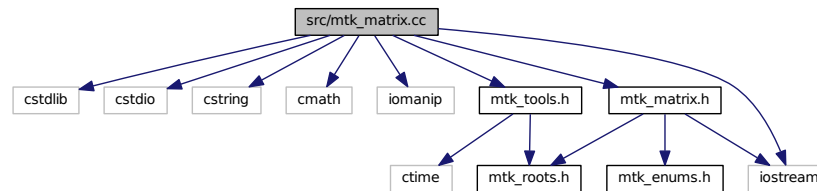
Implementing the representation of a matrix in the MTK.

```

#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:



### 17.77.1 Detailed Description

Implementation 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.cc](#).

## 17.78 mtk\_matrix.cc

```

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00010 /*
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00013
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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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```

```

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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 <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     return ld_;
00134 }
00135
00136 int mtk::Matrix::num_zero() const noexcept {
00137     return num_zero_;
00138 }
00139
00140 int mtk::Matrix::num_non_zero() const noexcept {
00141     return num_non_zero_;
00142 }
00143
00144 int mtk::Matrix::num_null() const noexcept {
00145     return num_null_;
00146 }
00147
00148 int mtk::Matrix::num_non_null() const noexcept {
00149     return num_non_null_;
00150 }
00151
00152 int mtk::Matrix::kl() const noexcept {
00153     return kl_;
00154 }
00155
00156 int mtk::Matrix::ku() const noexcept {
00157     return ku_;
00158 }
00159
00160 int mtk::Matrix::bandwidth() const noexcept {
00161     return bandwidth_;
00162 }
00163
00164 mtk::Real mtk::Matrix::rel_density() const noexcept {
00165     return rel_density_;
00166 }
00167
00168 mtk::Real mtk::Matrix::abs_sparsity() const noexcept {
00169     return abs_sparsity_;
00170 }
00171
00172 mtk::Real mtk::Matrix::rel_sparsity() const noexcept {
00173     return rel_sparsity_;
00174 }
00175
00176 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss)
00177     noexcept {
00178     #ifdef MTK_PERFORM_PREVENTIONS
00179     mtk::Tools::Prevent(!(ss == mtk::DENSE ||
00180         ss == mtk::BANDED ||
00181         ss == mtk::CRS),
00182         __FILE__, __LINE__, __func__);
00183     #endif
00184     storage_ = ss;
00185 }
00186
00187 void mtk::Matrix::set_ordering(const
00188     mtk::MatrixOrdering &oo) noexcept {
00189     #ifdef MTK_PERFORM_PREVENTIONS
00190     mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
00191         mtk::COL_MAJOR),
00192         __FILE__, __LINE__, __func__);
00193     #endif
00194     ordering_ = oo;
00195 }
00196
00197
00198
00199
00200
00201
00202
00203
00204
00205
00206
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
00245     rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00246     rel_sparsity_ = 1.0 - rel_density_;
00247 }
00248
00249 void mtk::Matrix::set_num_null(const int &in) noexcept {
00250
00251     #ifdef MTK_PERFORM_PREVENTIONS
00252     mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00253     #endif
00254
00255     num_null_ = in;
00256     num_non_null_ = num_values_ - num_null_;
00257
00258     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00259     abs_sparsity_ = 1.0 - abs_density_;
00260 }
00261
00262 void mtk::Matrix::IncreaseNumZero() noexcept {
00263
00264     num_zero_++;
00265     num_non_zero_ = num_values_ - num_zero_;
00266     rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00267     rel_sparsity_ = 1.0 - rel_density_;
00268 }
00269
00270 void mtk::Matrix::IncreaseNumNull() noexcept {
00271
00272     num_null_++;
00273     num_non_null_ = num_values_ - num_null_;
00274     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00275     abs_sparsity_ = 1.0 - abs_density_;
00276 }
00277
00278
00279
00280
00281
00282

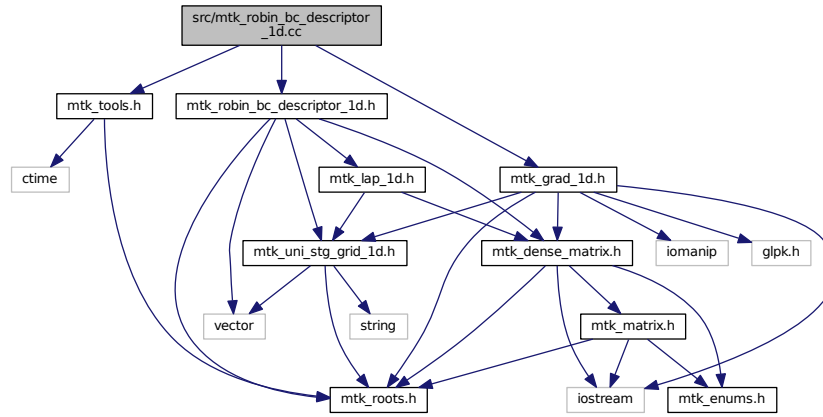
```

## 17.79 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:
```



### 17.79.1 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](#).

## 17.80 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
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
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00070
00071 The copyright holders provide no reassurances that the source code provided does
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
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00075 parties intellectual property rights.
00076
00077 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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 #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()
00109     const noexcept {
00110     return highest_order_diff_west_;
00111 }
00112
00113 int mtk::RobinBCDescriptor1D::highest_order_diff_east()
00114     const noexcept {
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         mtk::DenseMatrix coeffs(grad.mim_bndy());
00201
00205         mtk::Real idx = mtk::kOne/lap.delta();
00206
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     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 }

```

## 17.81 src/mtk\_robin\_bc\_descriptor\_2d.cc File Reference

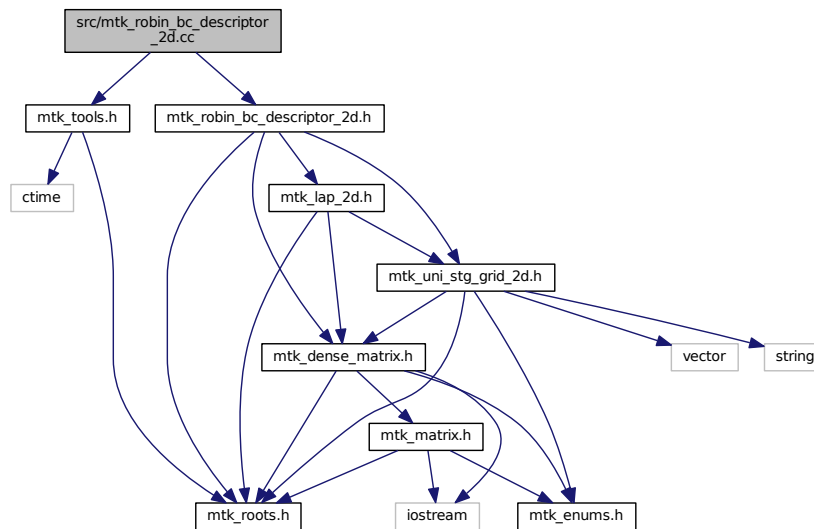
Impose Robin boundary conditions on the operators and on the grids.

```

#include "mtk_tools.h"
#include "mtk_robin_bc_descriptor_2d.h"

```

Include dependency graph for mtk\_robin\_bc\_descriptor\_2d.cc:



### 17.81.1 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

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Definition in file [mtk\\_robin\\_bc\\_descriptor\\_2d.cc](#).

## 17.82 mtk\_robin\_bc\_descriptor\_2d.cc

```

00001
00034 /*
00035 Copyright (C) 2015, Computational Science Research Center, San Diego State
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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00057
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00067
00068 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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00070 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00071 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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00073 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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()
00108     const noexcept {
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(
    mtk::CoefficientFunction1D cw) {
00128
00129     #ifdef MTK_PERFORM_PREVENTIONS
00130     mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00131     mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00132                         __FILE__, __LINE__, __func__);
00133     #endif
00134
00135     west_coefficients_.push_back(cw);
00136     highest_order_diff_west_++;
00137 }
00138
00141 void mtk::RobinBCDescriptor2D::PushBackEastCoeff(
    mtk::CoefficientFunction1D ce) {
00142
00143     #ifdef MTK_PERFORM_PREVENTIONS
00144     mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00145     mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00146                         __FILE__, __LINE__, __func__);
00147     #endif
00148
00149     east_coefficients_.push_back(ce);
00150     highest_order_diff_east_++;
00151 }
00152
00155 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff(
    mtk::CoefficientFunction1D cs) {
00156
00157     #ifdef MTK_PERFORM_PREVENTIONS
00158     mtk::Tools::Prevent(cs == nullptr, __FILE__, __LINE__, __func__);
00159     mtk::Tools::Prevent(highest_order_diff_south_ > 1,
00160                         __FILE__, __LINE__, __func__);
00161     #endif
00162
00163     south_coefficients_.push_back(cs);
00164     highest_order_diff_south_++;
00165 }
00166
00169 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff(
    mtk::CoefficientFunction1D cn) {
00170
00171     #ifdef MTK_PERFORM_PREVENTIONS
00172     mtk::Tools::Prevent(cn == nullptr, __FILE__, __LINE__, __func__);
00173     mtk::Tools::Prevent(highest_order_diff_north_ > 1,
00174                         __FILE__, __LINE__, __func__);
00175     #endif
00176
00177     north_coefficients_.push_back(cn);
00178     highest_order_diff_north_++;
00179 }
00180
00183 void mtk::RobinBCDescriptor2D::set_west_condition(
    mtk::Real (*west_condition)(const mtk::Real &yy,
                                const mtk::Real &tt)) noexcept {
00184
00185     #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 (
00231     const mtk::Lap2D &lap,
00232     const mtk::UniStgGrid2D &grid,
00233     mtk::DenseMatrix &matrix,
00234     const mtk::Real &time) const {
00235
00236     // For the south-west corner:
00237     auto cc = (south_coefficients_[0])(grid.west_bndy(), time);
00238
00239     #if MTK_VERBOSE_LEVEL > 2
00240     std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00241         matrix.num_cols() << " columns." << std::endl;
00242     std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00243     #endif
00244
00245     matrix.SetValue(0, 0, cc);
00246
00247     // Compute first centers per dimension.
00248     auto first_center_x = grid.west_bndy() + grid.delta_x()/
00249         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
00277 }
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
00290
00291
00292
00293 // For each entry on the diagonal:
00294 for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00295     // Evaluate next set spatial coordinates to evaluate the coefficient.
00296     mtk::Real xx{(grid.discrete_domain_x())[ii]};
00297     // Evaluate and assign the Dirichlet coefficient.
00298     mtk::Real cc = (south_coefficients_[0])(xx, time);
00299     matrix.SetValue(ii, ii, cc);
00300 }
00301
00302 if (highest_order_diff_south_ > 0) {
00303
00304 }
00305
00306 return true;
00307 }
00308
00309 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryNoSpace
(
00310     const mtk::Lap2D &lap,
00311     const mtk::UniStgGrid2D &grid,
00312     mtk::DenseMatrix &matrix,
00313     const mtk::Real &time) const {
00314
00315 int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00316
00317
00318 // For the north-west corner:
00319 mtk::Real cc =
00320     (north_coefficients_[0])(grid.west_bndy(), time);
00321
00322 #if MTK_VERBOSE_LEVEL > 2
00323 std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00324     matrix.num_cols() << " columns." << std::endl;
00325 std::cout << "Setting at " << north_offset << ' ' << north_offset <<
00326     std::endl;
00327 #endif
00328
00329 matrix.SetValue(north_offset, north_offset, cc);
00330
00331 // Compute first centers per dimension.
00332 auto first_center_x = grid.west_bndy() + grid.delta_x()/
00333     mtk::kTwo;
00334
00335 // For each entry on the diagonal (north boundary):
00336 for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00337     // Evaluate next set spatial coordinates to evaluate the coefficient.
00338     mtk::Real xx = first_center_x + ii*grid.delta_x();
00339     // Evaluate and assign the Dirichlet coefficient.
00340     cc = (north_coefficients_[0])(xx, time);
00341
00342     #if MTK_VERBOSE_LEVEL > 2
00343     std::cout << "Setting at " << north_offset + ii + 1 << ' ' <<
00344         north_offset + ii + 1 << std::endl;
00345     #endif
00346
00347     matrix.SetValue(north_offset + ii + 1, north_offset + ii + 1, cc);
00348 }
00349
00350
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 }
00366
00367 return true;
00370 }
00371
00372 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryWithSpace
00373 (
00374     const mtk::Lap2D &lap,
00375     const mtk::UniStgGrid2D &grid,
00376     mtk::DenseMatrix &matrix,
00377     const mtk::Real &time) const {
00378
00379     int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00380
00381     for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00382         mtk::Real xx{(grid.discrete_domain_x())[ii]};
00383         mtk::Real cc = (north_coefficients_[0])(xx, time);
00384         matrix.SetValue(north_offset + ii, north_offset + ii, cc);
00385     }
00386
00387     if (highest_order_diff_north_ > 0) {
00388     }
00389
00390     return true;
00391 }
00392
00393 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryNoSpace
00394 (
00395     const mtk::Lap2D &lap,
00396     const mtk::UniStgGrid2D &grid,
00397     mtk::DenseMatrix &matrix,
00398     const mtk::Real &time) const {
00399
00400     // For the south-west corner:
00401     auto cc = (west_coefficients_[0])(grid.south_bndy(), time);
00402
00403     #if MTK_VERBOSE_LEVEL > 2
00404     std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00405         matrix.num_cols() << " columns." << std::endl;
00406     std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00407     #endif
00408
00409     mtk::Real harmonic_mean = mtk::kOne/matrix.GetValue(0, 0) +
00410         mtk::kOne/cc;
00411     harmonic_mean = mtk::kTwo/harmonic_mean;
00412
00413     matrix.SetValue(0, 0, harmonic_mean);
00414
00415     int west_offset{grid.num_cells_x() + 1};
00416
00417     auto first_center_y = grid.south_bndy() + grid.delta_y()/
00418         mtk::kTwo;
00419
00420     // For each west entry on the diagonal (west boundary):
00421     for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00422         // Evaluate next set spatial coordinates to evaluate the coefficient.
00423         mtk::Real yy = first_center_y + ii*grid.delta_y();
00424         // Evaluate and assign the Dirichlet coefficient.
00425         cc = (west_coefficients_[0])(yy, time);
00426
00427         #if MTK_VERBOSE_LEVEL > 2
00428         std::cout << "Setting at " << west_offset + ii + 1 << ' ' <<
00429             west_offset + ii + 1 << std::endl;
00430         #endif
00431     }

```

```

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 }
00462
00463 return true;
00464 }
00465
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
00474
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     }
00489 }
00490
00491 return true;
00492 }
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
00501
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
00558 }
00559
00560 return true;
00561 }
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
00570
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
00585     }
00586
00587     return true;
00588 }
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
00733         mtk::Real yy = grid.south_bndy();
00734         (grid.discrete_field())[0] =
00735             ((grid.discrete_field())[0] + west_condition_(yy, time))/
00736             mtk::kTwo;
00737
00738         int west_offset{grid.num_cells_x() + 1 + 1};
00739         yy = yy + grid.delta_y()/mtk::kTwo;
00740         for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00741             #if MTK_VERBOSE_LEVEL > 2
00742                 std::cout << "Adding on " << west_offset << "-th position." << std::endl;
00743             #endif
00744             (grid.discrete_field())[west_offset] =
00745                 west_condition_(yy + ii*grid.delta_y(), time);
00746             west_offset += grid.num_cells_x() + 1 + 1;
00747         }
00748
00750         yy = grid.north_bndy();
00751         north_offset = (grid.num_cells_y() + 1)*(grid.num_cells_x() + 2);
00752         (grid.discrete_field())[north_offset] =
00753             ((grid.discrete_field())[north_offset] + west_condition_(yy, time))/
00754             mtk::kTwo;
00755
00756         yy = grid.south_bndy();
00757         int east_offset{grid.num_cells_x() + 1};
00758         (grid.discrete_field())[east_offset] =
00759             ((grid.discrete_field())[east_offset] + east_condition_(yy, time))/
00760             mtk::kTwo;
00761
00762         yy = yy + grid.delta_y()/mtk::kTwo;
00763         for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00764             east_offset += grid.num_cells_x() + 1 + 1;
00765             #if MTK_VERBOSE_LEVEL > 2
00766                 std::cout << "Adding on " << east_offset << "-th position." << std::endl;
00767             #endif
00768             (grid.discrete_field())[east_offset] =
00769                 east_condition_(yy + ii*grid.delta_y(), time);
00770         }
00771
00772         yy = grid.north_bndy();
00773         (grid.discrete_field())[north_offset + grid.num_cells_x() + 1] =
00774             ((grid.discrete_field())[north_offset + grid.num_cells_x() + 1] +
00775              east_condition_(yy, time))/mtk::kTwo;
00776
00777     } else {

```

```

00785
00787
00789     }
00790 }

```

## 17.83 src/mtk\_tools.cc File Reference

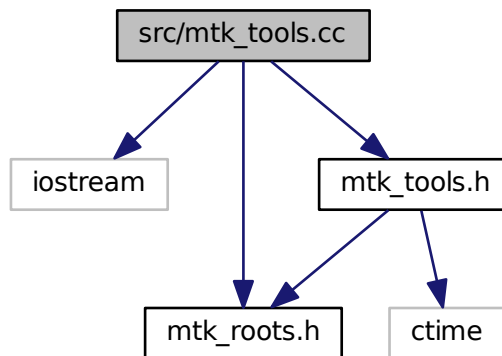
Implements a execution tool manager class.

```

#include <iostream>
#include "mtk_roots.h"
#include "mtk_tools.h"

```

Include dependency graph for mtk\_tools.cc:



### 17.83.1 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](#).

## 17.84 mtk\_tools.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
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00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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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
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
00066     if (lineno < 1) {
00067         std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00068         __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00069         exit(EXIT_FAILURE);
00070     }
00071
00072     if (condition) {
00073         std::cerr << fname << ": " << "Incorrect parameter at line " <<
00074         lineno << " (" << fxname << ")" << std::endl;
00075         exit(EXIT_FAILURE);
00076     }
00077 }
00078
00079
00080 int mtk::Tools::test_number_; // Used to control the correctness of the test.
00081
00082 mtk::Real mtk::Tools::duration_; // Duration of the current test.
00083
00084 clock_t mtk::Tools::begin_time_; // Used to time tests.
00085
00086 void mtk::Tools::BeginUnitTestNo(const int &nn) noexcept {
00087
00088     #if MTK_PERFORM_PREVENTIONS
00089     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00090     #endif
00091
00092     test_number_ = nn;
00093
00094     std::cout << "Beginning test " << nn << "." << std::endl;
00095     begin_time_ = clock();
00096 }
00097
00098 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 }

```

## 17.85 src/mtk\_uni\_stg\_grid\_1d.cc File Reference

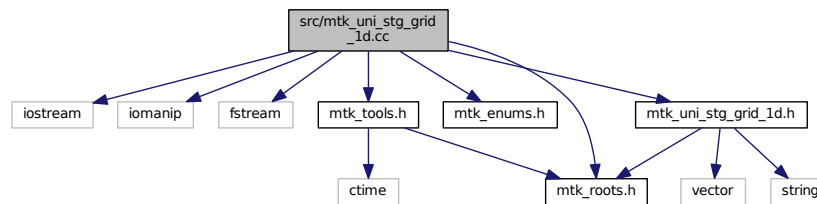
Implementation of an 1D uniform staggered grid.

```

#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)`

#### 17.85.1 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](#).

**17.86 mtk\_uni\_stg\_grid\_1d.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
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00033
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00042 parties intellectual property rights.
00043
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00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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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 "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
00073
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     return discrete_field_.data();
00168 }
00169 }
00170
00171 int mtk::UniStgGrid1D::num_cells_x() const {
00172     return num_cells_x_;
00173 }
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
00183     discrete_domain_x_.reserve(num_cells_x_ + 2);
00184
00185     discrete_domain_x_.push_back(west_bndy_x_);
00186     #ifdef MTK_PRECISION_DOUBLE
00187     auto first_center = west_bndy_x_ + delta_x_/2.0;
00188     #else
00189     auto first_center = west_bndy_x_ + delta_x_/2.0f;
00190     #endif
00191     discrete_domain_x_.push_back(first_center);
00192     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00193         discrete_domain_x_.push_back(first_center + ii*delta_x_);
00194     }
00195     discrete_domain_x_.push_back(east_bndy_x_);
00196
00197     discrete_field_.reserve(num_cells_x_ + 2);
00198     discrete_field_.push_back(ScalarField(west_bndy_x_));
00199     discrete_field_.push_back(ScalarField(first_center));
00200     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00201         discrete_field_.push_back(ScalarField(first_center + ii*delta_x_));
00202     }
00203     discrete_field_.push_back(ScalarField(east_bndy_x_));
00204 }
00205
00206 void mtk::UniStgGrid1D::BindVectorField(
00207     mtk::Real (*VectorField)(mtk::Real xx)) {
00208
00209     #ifdef MTK_PERFORM_PREVENTIONS
00210     mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00211     #endif
00212
00213     discrete_domain_x_.reserve(num_cells_x_ + 1);
00214
00215     discrete_domain_x_.push_back(west_bndy_x_);
00216     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00217         discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00218     }
00219     discrete_domain_x_.push_back(east_bndy_x_);
00220
00221     discrete_field_.reserve(num_cells_x_ + 1);
00222     discrete_field_.push_back(VectorField(west_bndy_x_));
00223     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00224         discrete_field_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00225     }
00226     discrete_field_.push_back(VectorField(east_bndy_x_));
00227 }
00228
00229 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00230     std::string space_name,

```

```

00242                                     std::string field_name) const {
00243
00244     std::ofstream output_dat_file; // Output file.
00245     output_dat_file.open(filename);
00246
00247     if (!output_dat_file.is_open()) {
00248         return false;
00249     }
00250
00251     output_dat_file << "#" << space_name << " " << field_name << std::endl;
00252     for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00253         output_dat_file << discrete_domain_x_[ii] << " " << discrete_field_[ii] <<
00254             std::endl;
00255     }
00256
00257     output_dat_file.close();
00258
00259     return true;
00260 }
00261

```

## 17.87 src/mtk\_uni\_stg\_grid\_2d.cc File Reference

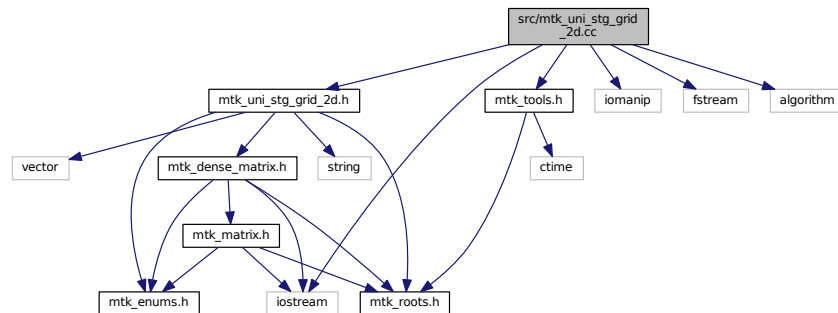
Implementation of a 2D uniform staggered grid.

```

#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)`

### 17.87.1 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](#).

## 17.88 mtk\_uni\_stg\_grid\_2d.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
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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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_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
00075
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
00089
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.
00158               discrete_domain_x_.size(),
00159               discrete_domain_x_.begin());
00160     std::copy(grid.discrete_domain_y_.begin(),
00161               grid.discrete_domain_y_.begin() + grid.
00162               discrete_domain_y_.size(),
00163               discrete_domain_y_.begin());
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     nature_ = nature;
00189
00190     west_bndy_ = west_bndy;
00191     east_bndy_ = east_bndy;
00192     num_cells_x_ = num_cells_x;
00193
00194     south_bndy_ = south_bndy;
00195     north_bndy_ = north_bndy;
00196     num_cells_y_ = num_cells_y;
00197
00198     delta_x_ = (east_bndy_ - west_bndy_) / ((mtk::Real) num_cells_x);
00199     delta_y_ = (north_bndy_ - south_bndy_) / ((mtk::Real) num_cells_y);
00200 }
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     return south_bndy_;
00237 }
00238
00239
00240 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00241     return north_bndy_;
00242 }
00243
00244
00245 int mtk::UniStgGrid2D::num_cells_y() const {
00246     return num_cells_y_;
00247 }
00248
00249
00250 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00251     return delta_y_;
00252 }
00253
00254
00255 bool mtk::UniStgGrid2D::Bound() const {
00256     return discrete_field_.size() != 0;
00257 }
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     return discrete_field_.data();
00267 }
00268
00269
00270 void mtk::UniStgGrid2D::BindScalarField(
00271     Real (*ScalarField)(const Real &xx, const Real &yy)) {
00272
00273     #ifdef MTK_PERFORM_PREVENTIONS
00274     mtk::Tools::Prevent(nature_ != mtk::SCALAR, __FILE__, __LINE__, __func__);
00275     #endif
00276
00277     discrete_domain_x_.reserve(num_cells_x_ + 2);
00278
00279     discrete_domain_x_.push_back(west_bndy_);
00280     #ifdef MTK_PRECISION_DOUBLE
00281     auto first_center = west_bndy_ + delta_x_/2.0;
00282     #else
00283     auto first_center = west_bndy_ + delta_x_/2.0f;
00284     #endif
00285     discrete_domain_x_.push_back(first_center);
00286     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00287         discrete_domain_x_.push_back(first_center + ii*delta_x_);
00288     }
00289     discrete_domain_x_.push_back(east_bndy_);
00290
00291     discrete_domain_y_.reserve(num_cells_y_ + 2);
00292
00293     discrete_domain_y_.push_back(south_bndy_);
00294     #ifdef MTK_PRECISION_DOUBLE
00295     first_center = south_bndy_ + delta_x_/2.0;
00296     #else
00297     first_center = south_bndy_ + delta_x_/2.0f;
00298     #endif
00299     discrete_domain_y_.push_back(first_center);
00300     for (auto ii = 1; ii < num_cells_y_; ++ii) {
00301         discrete_domain_y_.push_back(first_center + ii*delta_y_);
00302     }
00303     discrete_domain_y_.push_back(north_bndy_);
00304
00305     discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));

```

```

00312
00313     for (int ii = 0; ii < num_cells_y_ + 2; ++ii) {
00314         for (int jj = 0; jj < num_cells_x_ + 2; ++jj) {
00315             #if MTK_VERBOSE_LEVEL > 6
00316                 std::cout << "Pushing value for x = " << discrete_domain_x_[jj] <<
00317                     " y = " << discrete_domain_y_[ii] << std::endl;
00318             #endif
00319             discrete_field_.push_back(ScalarField(discrete_domain_x_[jj],
00320                 discrete_domain_y_[ii]));
00321         }
00322     }
00323 }
00324
00325 void mtk::UniStgGrid2D::BindVectorFieldPComponent(
00326     mtk::Real (*VectorField)(const mtk::Real &xx, const
00327     mtk::Real &yy)) {
00328     int mm{num_cells_x_};
00329     int nn{num_cells_y_};
00330
00331     int total{nn*(mm + 1) + mm*(nn + 1)};
00332
00333     #ifdef MTK_PRECISION_DOUBLE
00334     double half_delta_x{delta_x_/2.0};
00335     double half_delta_y{delta_y_/2.0};
00336     #else
00337     float half_delta_x{delta_x_/2.0f};
00338     float half_delta_y{delta_y_/2.0f};
00339     #endif
00340
00341     // We need every data point of the discrete domain; i.e. we need all the
00342     // nodes and all the centers. There are mm centers for the x direction, and
00343     // nn centers for the y direction. Since there is one node per center, that
00344     // amounts to 2*mm. If we finally consider the final boundary node, it
00345     // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00346     // y direction, this amounts to 2*nn + 1.
00347
00348     discrete_domain_x_.reserve(2*mm + 1);
00349
00350     discrete_domain_x_.push_back(west_bndy_);
00351     for (int ii = 1; ii < (2*mm + 1); ++ii) {
00352         discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00353     }
00354
00355     discrete_domain_y_.reserve(2*nn + 1);
00356
00357     discrete_domain_y_.push_back(south_bndy_);
00358     for (int ii = 1; ii < (2*nn + 1); ++ii) {
00359         discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00360     }
00361
00362     discrete_field_.reserve(total);
00363
00364     // For each y-center.
00365     for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00366         // Bind all of the x-nodes for this y-center.
00367         for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00368             discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00369                 discrete_domain_y_[ii]));
00370         }
00371
00372         #if MTK_VERBOSE_LEVEL > 6
00373             std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00374                 discrete_domain_y_[ii] << " = " <<
00375                 VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00376         #endif
00377     }
00378 }
00379
00380 #if MTK_VERBOSE_LEVEL > 6
00381 std::cout << std::endl;
00382 #endif
00383 }
00384
00385 void mtk::UniStgGrid2D::BindVectorFieldQComponent(
00386     mtk::Real (*VectorField)(const mtk::Real &xx, const
00387     mtk::Real &yy)) {
00388     int mm{num_cells_x_};

```

```

00394 int nn{num_cells_y_};
00395
00397
00398 // For each y-node.
00399 for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00400
00401     // Bind all of the x-center for this y-node.
00402     for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00403         discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00404                                                discrete_domain_y_[ii]));
00405
00406         #if MTK_VERBOSE_LEVEL > 6
00407         std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00408             discrete_domain_y_[ii] << " = " <<
00409             VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00410         #endif
00411     }
00412 }
00413 #if MTK_VERBOSE_LEVEL > 6
00414 std::cout << std::endl;
00415 #endif
00416 }
00417
00418 void mtk::UniStgGrid2D::BindVectorField(
00419     Real (*VectorFieldPComponent)(const Real &xx, const Real &yy),
00420     Real (*VectorFieldQComponent)(const Real &xx, const Real &yy)) {
00421
00422     #ifdef MTK_PERFORM_PREVENTIONS
00423     mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00424     #endif
00425
00426     BindVectorFieldPComponent(VectorFieldPComponent);
00427     BindVectorFieldQComponent(VectorFieldQComponent);
00428 }
00429
00430 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00431                                     std::string space_name_x,
00432                                     std::string space_name_y,
00433                                     std::string field_name) const {
00434
00435     std::ofstream output_dat_file; // Output file.
00436
00437     output_dat_file.open(filename);
00438
00439     if (!output_dat_file.is_open()) {
00440         return false;
00441     }
00442
00443     if (nature_ == mtk::SCALAR) {
00444         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00445             field_name << std::endl;
00446
00447         int idx{};
00448         for (unsigned int ii = 0; ii < discrete_domain_y_.size(); ++ii) {
00449             for (unsigned int jj = 0; jj < discrete_domain_x_.size(); ++jj) {
00450                 output_dat_file << discrete_domain_x_[jj] << ' ' <<
00451                     discrete_domain_y_[ii] << ' ' <<
00452                     discrete_field_[idx] <<
00453                     std::endl;
00454                 idx++;
00455             }
00456             output_dat_file << std::endl;
00457         }
00458     } else {
00459         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00460             field_name << std::endl;
00461
00462         output_dat_file << "# Horizontal component:" << std::endl;
00463
00464         int mm{num_cells_x_};
00465         int nn{num_cells_y_};
00466
00467         // For each y-center.
00468         int idx{};
00469         for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00470             // Bind all of the x-nodes for this y-center.
00471             for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00472
00473                 output_dat_file << discrete_domain_x_[jj] << ' ' <<
00474                     discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<

```

```

00477         mtk::kZero << std::endl;
00478
00479         ++idx;
00480     }
00481 }
00482
00483 int p_offset{nn*(mm + 1) - 1};
00484 idx = 0;
00485 output_dat_file << "# Vertical component:" << std::endl;
00486 // For each y-node.
00487 for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00488     // Bind all of the x-center for this y-node.
00489     for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00490
00491         output_dat_file << discrete_domain_x[jj] << ' ' <<
00492             discrete_domain_y[ii] << ' ' << mtk::kZero << ' ' <<
00493             discrete_field[p_offset + idx] << std::endl;
00494
00495         ++idx;
00496     }
00497 }
00498 }
00499 }
00500
00501 output_dat_file.close();
00502
00503 return true;
00504 }

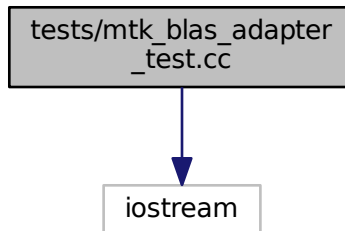
```

## 17.89 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](#) ()

#### 17.89.1 Detailed Description

**Author**

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_blas\\_adapter\\_test.cc](#).

**17.89.2 Function Documentation****17.89.2.1 int main ( )**

Definition at line 109 of file [mtk\\_blas\\_adapter\\_test.cc](#).

**17.90 mtk\_blas\_adapter\_test.cc**

```
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00008 /*
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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 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

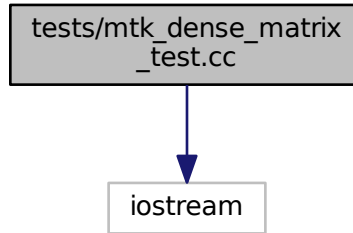
```

## 17.91 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` ()

### 17.91.1 Detailed Description

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file `mtk_dense_matrix_test.cc`.

### 17.91.2 Function Documentation

#### 17.91.2.1 int main ( )

Definition at line 330 of file `mtk_dense_matrix_test.cc`.

## 17.92 mtk\_dense\_matrix\_test.cc

```

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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
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00023

```

```

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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

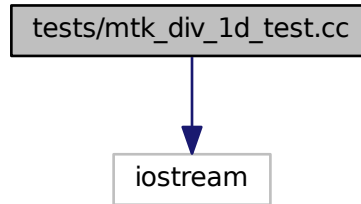
```

## 17.93 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](#) ()

### 17.93.1 Detailed Description

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_div\\_1d\\_test.cc](#).

### 17.93.2 Function Documentation

#### 17.93.2.1 int main ( )

Definition at line [288](#) of file [mtk\\_div\\_1d\\_test.cc](#).

## 17.94 mtk\_div\_1d\_test.cc

```

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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:
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,

```

```
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00027
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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 #include <iostream>
00056 #include "mtk.h"
00057
00058 void TestDefaultConstructorFactoryMethodDefault() {
00059
00060     mtk::Tools::BeginUnitTestNo(1);
00061
00062     mtk::Div1D div2;
00063
00064     bool assertion = div2.ConstructDiv1D();
00065
00066     if (!assertion) {
00067         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00068     }
00069
00070     mtk::Tools::EndUnitTestNo(1);
00071     mtk::Tools::Assert(assertion);
00072 }
00073
00074 void TestDefaultConstructorFactoryMethodFourthOrder() {
00075
00076     mtk::Tools::BeginUnitTestNo(2);
00077
00078     mtk::Div1D div4;
00079
00080     bool assertion = div4.ConstructDiv1D(4);
00081
00082     if (!assertion) {
00083         std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00084     }
00085
00086     mtk::Tools::EndUnitTestNo(2);
00087     mtk::Tools::Assert(assertion);
00088 }
00089
00090 void TestDefaultConstructorFactoryMethodSixthOrder() {
00091
00092     mtk::Tools::BeginUnitTestNo(3);
00093
00094     mtk::Div1D div6;
00095
00096     bool assertion = div6.ConstructDiv1D(6);
00097
00098     if (!assertion) {
00099         std::cerr << "Mimetic div (6th order) could not be built." << std::endl;
00100     }
00101
00102     mtk::Tools::EndUnitTestNo(3);
00103     mtk::Tools::Assert(assertion);
00104 }
00105
```

```

00106 }
00107
00108 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00109     mtk::Tools::BeginUnitTestNo(4);
00110
00111     mtk::Div1D div8;
00112
00113     bool assertion = div8.ConstructDiv1D(8);
00114
00115     if (!assertion) {
00116         std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00117     }
00118
00119     mtk::Tools::EndUnitTestNo(4);
00120     mtk::Tools::Assert(assertion);
00121 }
00122
00123 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00124     mtk::Tools::BeginUnitTestNo(5);
00125
00126     mtk::Div1D div10;
00127
00128     bool assertion = div10.ConstructDiv1D(10);
00129
00130     if (!assertion) {
00131         std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00132     }
00133
00134     mtk::Tools::EndUnitTestNo(5);
00135     mtk::Tools::Assert(assertion);
00136 }
00137
00138 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00139     mtk::Tools::BeginUnitTestNo(6);
00140
00141     mtk::Div1D div12;
00142
00143     bool assertion = div12.ConstructDiv1D(12);
00144
00145     if (!assertion) {
00146         std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00147     }
00148
00149     mtk::Tools::EndUnitTestNo(6);
00150     mtk::Tools::Assert(assertion);
00151 }
00152
00153 void TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold() {
00154     mtk::Tools::BeginUnitTestNo(7);
00155
00156     mtk::Div1D div14;
00157
00158     bool assertion = div14.ConstructDiv1D(14);
00159
00160     if (!assertion) {
00161         std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00162     }
00163
00164     mtk::Tools::EndUnitTestNo(7);
00165     mtk::Tools::Assert(assertion);
00166 }
00167
00168 void TestSecondOrderReturnAsDenseMatrixWithGrid() {
00169     mtk::Tools::BeginUnitTestNo(8);
00170
00171     mtk::Div1D div2;
00172
00173     bool assertion = div2.ConstructDiv1D();
00174
00175     if (!assertion) {
00176         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00177     }
00178
00179     mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00180
00181     mtk::DenseMatrix div2m(div2.ReturnAsDenseMatrix(grid));
00182 }
00183
00184
00185
00186

```

```

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

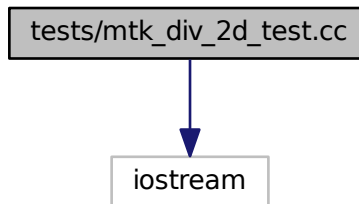
```

## 17.95 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 ()`

#### 17.95.1 Detailed Description

##### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_div\\_2d\\_test.cc](#).



## 17.95.2 Function Documentation

### 17.95.2.1 int main ( )

Definition at line 139 of file [mtk\\_div\\_2d\\_test.cc](#).

## 17.96 mtk\_div\_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
00023
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::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

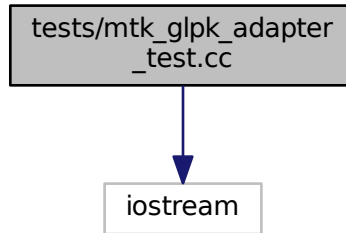
```

## 17.97 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](#) ()

### 17.97.1 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](#).

### 17.97.2 Function Documentation

#### 17.97.2.1 int main ( )

Definition at line [81](#) of file [mtk\\_glpk\\_adapter\\_test.cc](#).

## 17.98 mtk\_glpk\_adapter\_test.cc

```

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00010 /*
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00013
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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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00026 3. Redistributions in binary form must reproduce the above copyright notice,
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00030 4. Usage of the binary form on proprietary applications shall require explicit
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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::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

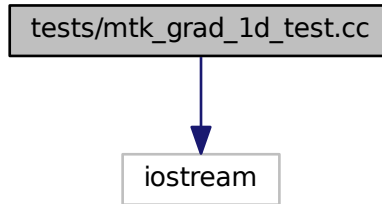
```

## 17.99 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](#) ()

### 17.99.1 Detailed Description

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_grad\\_1d\\_test.cc](#).

### 17.99.2 Function Documentation

#### 17.99.2.1 int main ( )

Definition at line [319](#) of file [mtk\\_grad\\_1d\\_test.cc](#).

## 17.100 mtk\_grad\_1d\_test.cc

```

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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 #include <iostream>
00056 #include "mtk.h"
00057
00058 void TestDefaultConstructorFactoryMethodDefault() {
00059     mtk::Tools::BeginUnitTestNo(1);
00060
00061     mtk::Grad1D grad2;
00062
00063     bool assertion = grad2.ConstructGrad1D();
00064
00065     if (!assertion) {
00066         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00067     }
00068
00069     std::cout << grad2 << std::endl;
00070
00071     mtk::Tools::EndUnitTestNo(1);
00072     mtk::Tools::Assert(assertion);
00073 }
00074
00075 void TestDefaultConstructorFactoryMethodFourthOrder() {
00076     mtk::Tools::BeginUnitTestNo(2);
00077
00078     mtk::Grad1D grad4;
00079
00080     bool assertion = grad4.ConstructGrad1D(4);
00081
00082     if (!assertion) {
00083         std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00084     }
00085
00086     std::cout << grad4 << std::endl;
00087
00088     mtk::Tools::EndUnitTestNo(2);
00089     mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestDefaultConstructorFactoryMethodSixthOrder() {
00093     mtk::Tools::BeginUnitTestNo(3);
00094
00095     mtk::Grad1D grad6;
00096
00097     bool assertion = grad6.ConstructGrad1D(6);
00098
00099     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
00243 (10));
00244
00245     std::cout << grad4m << std::endl;
00246
00247     mtk::Tools::EndUnitTestNo(7);
00248     mtk::Tools::Assert(assertion);
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

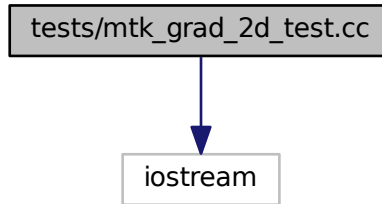
```

## 17.101 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 ()`

### 17.101.1 Detailed Description

#### Author

: Eduardo J. Sanchez (ejspeiro) - [esanchez at mail dot sdsu dot edu](mailto:esanchez@mail.sdsu.edu)

Definition in file [mtk\\_grad\\_2d\\_test.cc](#).

### 17.101.2 Function Documentation

#### 17.101.2.1 `int main ( )`

Definition at line [139](#) of file [mtk\\_grad\\_2d\\_test.cc](#).

## 17.102 `mtk_grad_2d_test.cc`

```
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00008 /*
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00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
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00052 */
00053
00054 #if __cplusplus == 201103L
00055 #include <cmath>
00056 #include <ctime>
00057 #include <iostream>
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactory() {
00061     mtk::Tools::BeginUnitTestNo(1);
00062
00063     mtk::Grad2D gg;
00064
00065     mtk::Real aa = 0.0;
00066     mtk::Real bb = 1.0;
00067     mtk::Real cc = 0.0;
00068     mtk::Real dd = 1.0;
00069
00070     int nn = 5;
00071     int mm = 5;
00072
00073     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00074
00075     bool assertion = gg.ConstructGrad2D(ggg);
00076
00077     if (!assertion) {
00078         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00079     }
00080
00081     mtk::Tools::EndUnitTestNo(1);
00082     mtk::Tools::Assert(assertion);
00083 }
00084
00085 void TestReturnAsDenseMatrixWriteToFile() {
00086     mtk::Tools::BeginUnitTestNo(2);
00087
00088     mtk::Grad2D gg;
00089
00090     mtk::Real aa = 0.0;
00091     mtk::Real bb = 1.0;
00092     mtk::Real cc = 0.0;
00093     mtk::Real dd = 1.0;
00094
00095     int nn = 5;
00096     int mm = 5;
00097
00098     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00099
00100     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

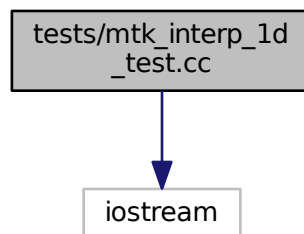
```

### 17.103 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](#) ()

### 17.103.1 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](#).

### 17.103.2 Function Documentation

#### 17.103.2.1 int main ( )

Definition at line 113 of file [mtk\\_interp\\_1d\\_test.cc](#).

## 17.104 mtk\_interp\_1d\_test.cc

```
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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

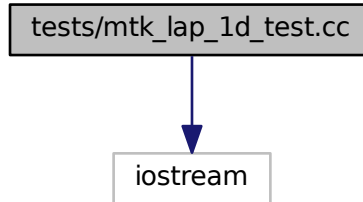
```

## 17.105 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](#) ()

### 17.105.1 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](#).

### 17.105.2 Function Documentation

#### 17.105.2.1 int main ( )

Definition at line [193](#) of file [mtk\\_lap\\_1d\\_test.cc](#).

## 17.106 mtk\_lap\_1d\_test.cc

```
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00010 /*
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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
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```

```

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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();

```

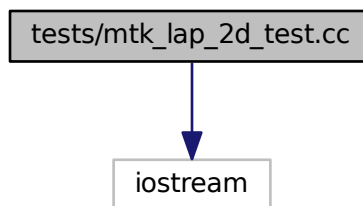
```
00188     TestReturnAsDenseMatrix();
00189 }
00190
00191 #else
00192 #include <iostream>
00193 int main () {
00194     std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00195     std::cout << "Exiting..." << std::endl;
00196 }
00197 #endif
```

## 17.107 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 ()`

#### 17.107.1 Detailed Description

##### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_lap\\_2d\\_test.cc](#).

#### 17.107.2 Function Documentation

##### 17.107.2.1 `int main ( )`

Definition at line [139](#) of file [mtk\\_lap\\_2d\\_test.cc](#).

## 17.108 mtk\_lap\_2d\_test.cc

```

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00011
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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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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

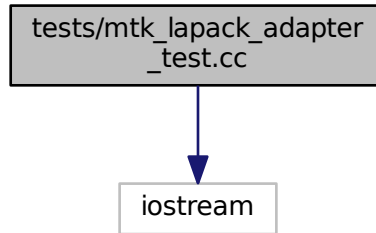
```

## 17.109 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](#) ()

### 17.109.1 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](#).

### 17.109.2 Function Documentation

#### 17.109.2.1 int main ( )

Definition at line [81](#) of file [mtk\\_lapack\\_adapter\\_test.cc](#).

## 17.110 mtk\_lapack\_adapter\_test.cc

```

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00021 should be developed and included in any deliverable.

```

```

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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

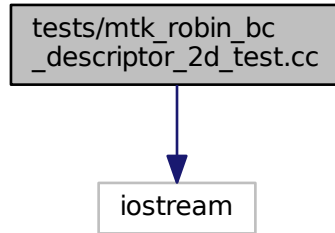
```

## 17.111 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` ()

### 17.111.1 Detailed Description

#### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_robin\\_bc\\_descriptor\\_2d\\_test.cc](#).

### 17.111.2 Function Documentation

#### 17.111.2.1 int main ( )

Definition at line 197 of file [mtk\\_robin\\_bc\\_descriptor\\_2d\\_test.cc](#).

## 17.112 mtk\_robin\_bc\_descriptor\_2d\_test.cc

```

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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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00023

```

```

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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 && llm.WriteToFile("mtk_bc_descriptor_2d_test_02.dat");
00128
00129     mtk::Tools::EndUnitTestNo(2);
00130     mtk::Tools::Assert(assertion);
00131 }
00132
00133 mtk::Real ScalarField(const mtk::Real &xx, const mtk::Real &yy) {
00134
00135     mtk::Real aux(-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy);
00136
00137     return xx*yy*exp(aux);
00138 }
00139
00140 mtk::Real HomogeneousDiricheletBC(const mtk::Real &xx,
00141                                   const mtk::Real &tt) {
00142
00143     return mtk::kZero;
00144 }
00145
00146 void TestImposeOnGrid() {
00147
00148     mtk::Tools::BeginUnitTestNo(3);
00149
00150     mtk::Real aa = 0.0;
00151     mtk::Real bb = 1.0;
00152     mtk::Real cc = 0.0;
00153     mtk::Real dd = 1.0;
00154
00155     int nn = 5;
00156     int mm = 5;
00157
00158     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00159
00160     gg.BindScalarField(ScalarField);
00161
00162     mtk::RobinBCDescriptor2D desc;
00163
00164     desc.set_west_condition(HomogeneousDiricheletBC);
00165     desc.set_east_condition(HomogeneousDiricheletBC);
00166     desc.set_south_condition(HomogeneousDiricheletBC);
00167     desc.set_north_condition(HomogeneousDiricheletBC);
00168
00169     desc.ImposeOnGrid(gg);
00170
00171     bool assertion{gg.WriteToFile("mtk_bc_descriptor_2d_test_03.dat",
00172                                   "x",
00173                                   "y",
00174                                   "u(x,y) ")};
00175
00176     if(!assertion) {
00177         std::cerr << "Error writing to file." << std::endl;
00178     }
00179
00180     mtk::Tools::EndUnitTestNo(3);
00181     mtk::Tools::Assert(assertion);
00182 }
00183
00184 int main () {
00185

```

```

00186     std::cout << "Testing mtk::RobinBCDescriptor2D class." << std::endl;
00187
00188     TestDefaultConstructorGetters();
00189     TestPushBackImposeOnLaplacianMatrix();
00190     TestImposeOnGrid();
00191 }
00192
00193 #else
00194 #include <iostream>
00195 using std::cout;
00196 using std::endl;
00197 int main () {
00198     cout << "This code HAS to be compiled with support for C++11." << endl;
00199     cout << "Exiting..." << endl;
00200 }
00201 #endif

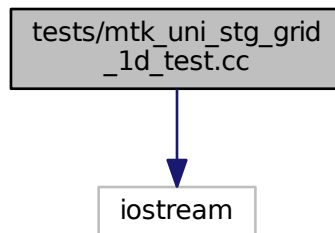
```

## 17.113 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 ()`

#### 17.113.1 Detailed Description

##### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_uni\\_stg\\_grid\\_1d\\_test.cc](#).

#### 17.113.2 Function Documentation

## 17.113.2.1 int main ( )

Definition at line 172 of file [mtk\\_uni\\_stg\\_grid\\_1d\\_test.cc](#).

## 17.114 mtk\_uni\_stg\_grid\_1d\_test.cc

```

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00008 /*
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00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
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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 #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

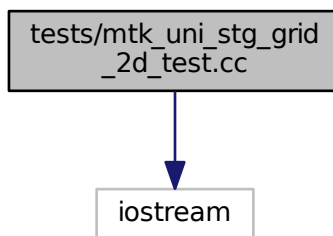
```

## 17.115 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 ()`

#### 17.115.1 Detailed Description

##### Author

: Eduardo J. Sanchez (ejspeiro) - esanchez at mail dot sdsu dot edu

Definition in file [mtk\\_uni\\_stg\\_grid\\_2d\\_test.cc](#).

#### 17.115.2 Function Documentation

## 17.115.2.1 int main ( )

Definition at line 202 of file [mtk\\_uni\\_stg\\_grid\\_2d\\_test.cc](#).

## 17.116 mtk\_uni\_stg\_grid\_2d\_test.cc

```

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00016 and a copy of the modified files should be reported once modifications are
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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.
00071         delta_y() == mtk::kZero);
00072 }
00073
00074 void
00075 TestConstructWithWestEastNumCellsXSouthNorthBndyNumCellsYostreamOperator() {
00076
00077

```

```

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) <
00093         mtk::kDefaultTolerance);
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
00153     mtk::Real &yy) {
00154
00155     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     TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYStreamOperator();
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

```



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