

## 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](https://www.sdsu.edu/~ejspeiro)
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

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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>
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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.cs.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::BCDescriptor2D::ImposeOnSouthBoundary` (`const mtk::UniStgGrid2D &grid, mtk::DenseMatrix &matrix, const int &order_accuracy`) `const`**

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

**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::Tools::Prevent` (`const bool complement, const char *const fname, int lineno, const char *const fname)` `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_u` ()**

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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Data structures. . . . .	37
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## Chapter 11

# Namespace Index

### 11.1 Namespace List

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---------------------	---	--------------------



## Chapter 12

# Class Index

### 12.1 Class List

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<a href="#">mtk::BCDescriptor2D</a>	Enforces boundary conditions in either the operator or the grid . . . . .	53
<a href="#">mtk::BLASAdapter</a>	Adapter class for the BLAS API . . . . .	69
<a href="#">mtk::DenseMatrix</a>	Defines a common dense matrix, using a 1D array . . . . .	75
<a href="#">mtk::Div1D</a>	Implements a 1D mimetic divergence operator . . . . .	92
<a href="#">mtk::Div2D</a>	Implements a 2D mimetic divergence operator . . . . .	104
<a href="#">mtk::GLPKAdapter</a>	Adapter class for the GLPK API . . . . .	108
<a href="#">mtk::Grad1D</a>	Implements a 1D mimetic gradient operator . . . . .	111
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<a href="#">mtk::Interp1D</a>	Implements a 1D interpolation operator . . . . .	127
<a href="#">mtk::Interp2D</a>	Implements a 2D interpolation operator . . . . .	131
<a href="#">mtk::Lap1D</a>	Implements a 1D mimetic Laplacian operator . . . . .	134
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<a href="#">mtk::LAPACKAdapter</a>	Adapter class for the LAPACK API . . . . .	143
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## Chapter 13

# File Index

### 13.1 File List

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Includes the definition of the class Div1D	218
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Includes the definition of the class Grad2D	230
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Includes the definition of the class Interp1D	233
include/ <a href="#">mtk_interp_2d.h</a>	
Includes the definition of the class Interp2D	236
include/ <a href="#">mtk_lap_1d.h</a>	
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<a href="#">include/mtk_lap_2d.h</a>	Includes the implementation of the class Lap2D . . . . .	240
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<a href="#">include/mtk_matrix.h</a>	Definition of the representation of a matrix in the MTK . . . . .	245
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<a href="#">src/mtk_grad_2d.cc</a>	Implements the class Grad2D . . . . .	333
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<a href="#">src/mtk_lap_1d.cc</a>	Includes the implementation of the class Lap1D . . . . .	339
<a href="#">src/mtk_lap_2d.cc</a>	Includes the implementation of the class Lap2D . . . . .	343
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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::BCDescriptor1D](#)  
*Enforces boundary conditions in either the operator or the grid.*
- class [mtk::BCDescriptor2D](#)  
*Enforces boundary conditions in either the operator or the grid.*
- 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.*

### Typedefs

- typedef [Real](#)(\* [mtk::CoefficientFunction2D](#) )(const [Real](#) &, const [Real](#) &)  
*A function of a BC coefficient evaluated on a 2D domain.*

#### 14.7.1 Detailed Description

Mimetic operators.

#### 14.7.2 Typedef Documentation

##### 14.7.2.1 [mtk::CoefficientFunction2D](#)

Definition at line 92 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

## Chapter 15

# Namespace Documentation

### 15.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

#### Classes

- class [BCDescriptor1D](#)  
*Enforces boundary conditions in either the operator or the grid.*
- class [BCDescriptor2D](#)  
*Enforces boundary conditions in either the operator or the grid.*
- 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 [Tools](#)  
*Tool manager class.*
- class [UniStgGrid1D](#)  
*Uniform 1D Staggered Grid.*
- class [UniStgGrid2D](#)  
*Uniform 2D Staggered Grid.*

## Typedefs

- typedef [Real](#)(\* [CoefficientFunction2D](#))(const [Real](#) &, const [Real](#) &)  
*A function of a BC coefficient evaluated on a 2D domain.*
- 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 )`

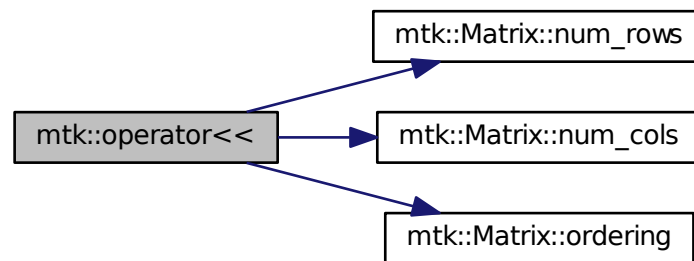
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

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](#).

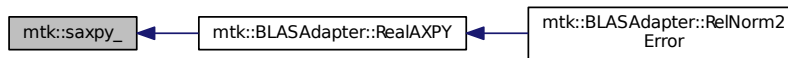
15.1.1.7 `std::ostream& mtk::operator<< ( std::ostream & stream, mtk::Div1D & in )`

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.

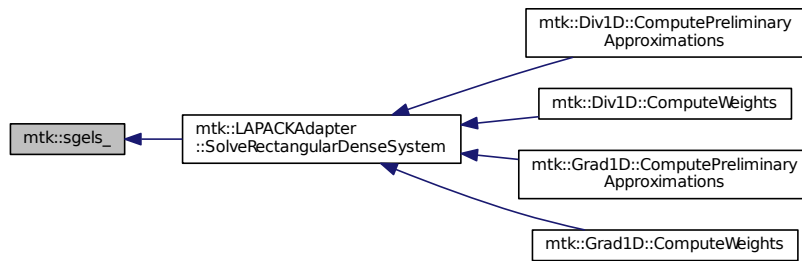
See also

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

## Parameters

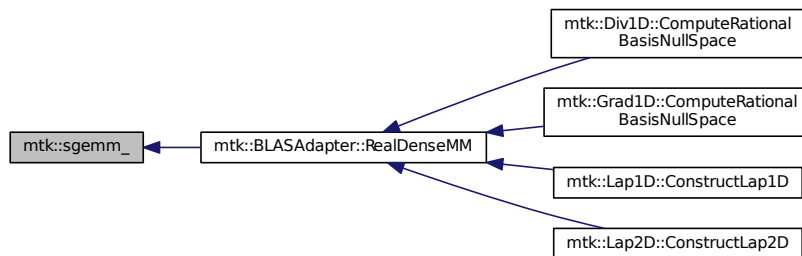
in	<i>trans</i>	Am I giving the transpose of the matrix?
in	<i>m</i>	The number of rows of the matrix a. $m \geq 0$ .
in	<i>n</i>	The number of columns of the matrix a. $n \geq 0$ .
in	<i>nrhs</i>	The number of right-hand sides.
in,out	<i>a</i>	On entry, the m-by-n matrix a.
in	<i>lda</i>	The leading 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)

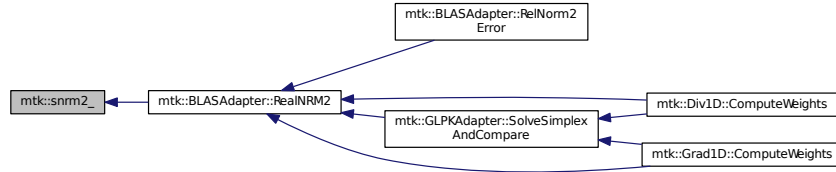
#### Parameters

<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.
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## Chapter 16

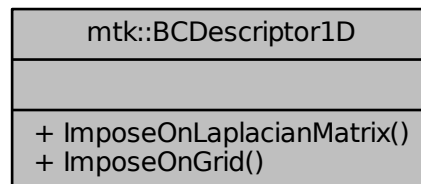
# Class Documentation

### 16.1 mtk::BCDescriptor1D Class Reference

Enforces boundary conditions in either the operator or the grid.

```
#include <mtk_bc_descriptor_1d.h>
```

Collaboration diagram for mtk::BCDescriptor1D:



#### Static Public Member Functions

- static void `ImposeOnLaplacianMatrix` (`DenseMatrix` &matrix, const std::vector< `Real` > &west, const std::vector< `Real` > &east)

*Enforces the condition on the Laplacian represented as matrix.*

- static void `ImposeOnGrid` (`UniStgGrid1D` &grid, const `Real` &epsilon, const `Real` &omega)

*Enforces the condition on the grid.*

#### 16.1.1 Detailed Description

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

Definition at line 78 of file `mtk_bc_descriptor_1d.h`.

## 16.1.2 Member Function Documentation

16.1.2.1 `void mtk::BCDescriptor1D::ImposeOnGrid ( mtk::UniStgGrid1D & grid, const Real & epsilon, const Real & omega )`  
`[static]`

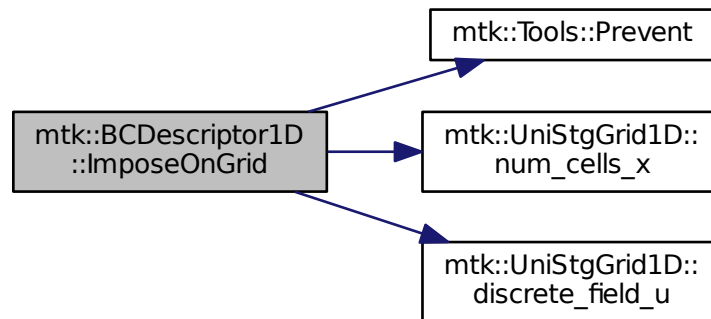
### Parameters

<i>in, out</i>	<i>grid</i>	Input grid.
<i>in</i>	<i>epsilon</i>	Actual BC for the east.
<i>in</i>	<i>omega</i>	Actual BC for the west.

1. Assign the west condition.
2. Assign the east condition.

Definition at line 89 of file [mtk\\_bc\\_descriptor\\_1d.cc](#).

Here is the call graph for this function:



16.1.2.2 `void mtk::BCDescriptor1D::ImposeOnLaplacianMatrix ( mtk::DenseMatrix & matrix, const std::vector< Real > & west, const std::vector< Real > & east )`  
`[static]`

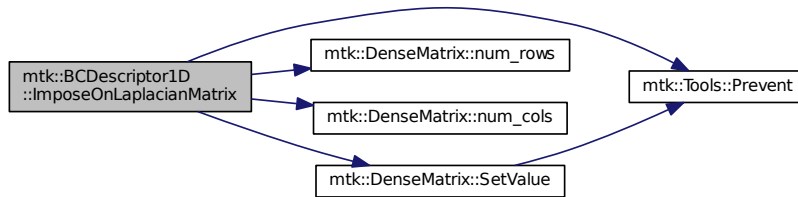
### Parameters

<i>in, out</i>	<i>matrix</i>	Input operator.
<i>in</i>	<i>west</i>	Array of values for the west boundary.
<i>in</i>	<i>east</i>	Array of values for the east boundary.

1. Assign the west array.
2. Assign the east array.

Definition at line 61 of file [mtk\\_bc\\_descriptor\\_1d.cc](#).

Here is the call graph for this function:



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

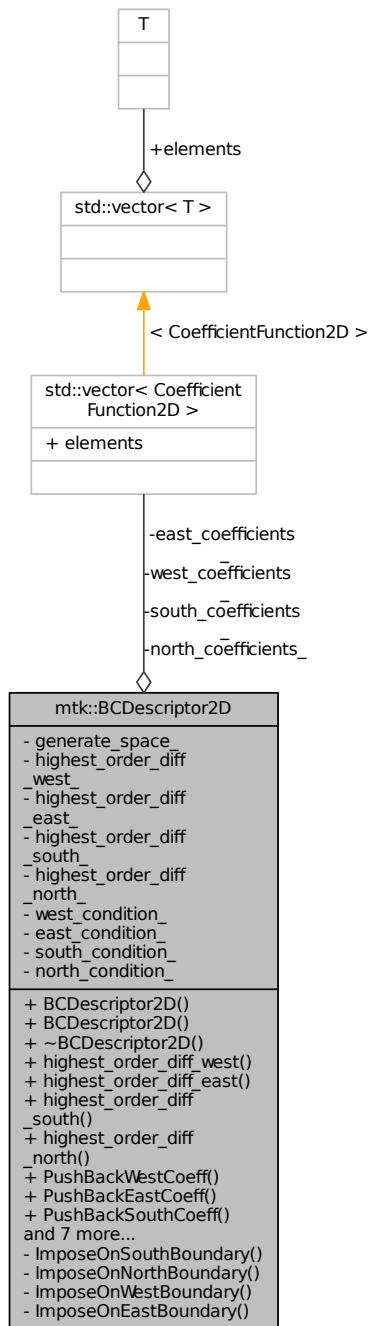
- [include/mtk\\_bc\\_descriptor\\_1d.h](#)
- [src/mtk\\_bc\\_descriptor\\_1d.cc](#)

## 16.2 mtk::BCDescriptor2D Class Reference

Enforces boundary conditions in either the operator or the grid.

```
#include <mtk_bc_descriptor_2d.h>
```

Collaboration diagram for mtk::BCDescriptor2D:



## Public Member Functions

- [BCDescriptor2D](#) ()

- Default constructor.*
- [BCDescriptor2D](#) (const [BCDescriptor2D](#) &desc)
- Copy constructor.*
- [~BCDescriptor2D](#) () 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](#) ([CoefficientFunction2D](#) cw)
- Push back coefficient function at west of lowest order diff. available.*
- void [PushBackEastCoeff](#) ([CoefficientFunction2D](#) ce)
- Push back coefficient function at east of lowest order diff. available.*
- void [PushBackSouthCoeff](#) ([CoefficientFunction2D](#) cs)
- Push back coefficient function south of lowest order diff. available.*
- void [PushBackNorthCoeff](#) ([CoefficientFunction2D](#) cn)
- Push back coefficient function north of lowest order diff. available.*
- void [set\\_west\\_condition](#) ([Real](#)(\*west\_condition)([Real](#) xx, [Real](#) yy)) noexcept
- Set boundary condition at west.*
- void [set\\_east\\_condition](#) ([Real](#)(\*east\_condition)([Real](#) xx, [Real](#) yy)) noexcept
- Set boundary condition at east.*
- void [set\\_south\\_condition](#) ([Real](#)(\*south\_condition)([Real](#) xx, [Real](#) yy)) noexcept
- Set boundary condition at south.*
- void [set\\_north\\_condition](#) ([Real](#)(\*north\_condition)([Real](#) xx, [Real](#) yy)) noexcept
- Set boundary condition at north.*
- void [ImposeOnLaplacianMatrix](#) (const [UniStgGrid2D](#) &grid, [DenseMatrix](#) &matrix, const int &order\_accuracy=2) const
- Imposes the condition on the operator represented as matrix.*
- void [ImposeOnGrid](#) ([UniStgGrid2D](#) &grid) const
- Imposes the condition on the grid.*

### Private Member Functions

- void [ImposeOnSouthBoundary](#) (const [mtk::UniStgGrid2D](#) &grid, [mtk::DenseMatrix](#) &matrix, const int &order\_accuracy) const
- Imposes the condition on the south boundary.*
- void [ImposeOnNorthBoundary](#) (const [mtk::UniStgGrid2D](#) &grid, [mtk::DenseMatrix](#) &matrix, const int &order\_accuracy) const
- Imposes the condition on the north boundary.*
- void [ImposeOnWestBoundary](#) (const [mtk::UniStgGrid2D](#) &grid, [mtk::DenseMatrix](#) &matrix, const int &order\_accuracy) const
- Imposes the condition on the west boundary.*
- void [ImposeOnEastBoundary](#) (const [mtk::UniStgGrid2D](#) &grid, [mtk::DenseMatrix](#) &matrix, const int &order\_accuracy) const
- Imposes the condition on the east boundary.*

## Private Attributes

- bool [generate\\_space\\_](#)  
*Should I generate coordinates as evaluate?*
- int [highest\\_order\\_diff\\_west\\_](#)  
*Highest order of differentiation for west.*
- int [highest\\_order\\_diff\\_east\\_](#)  
*Highest order of differentiation for east.*
- int [highest\\_order\\_diff\\_south\\_](#)  
*Highest order differentiation for south.*
- int [highest\\_order\\_diff\\_north\\_](#)  
*Highest order differentiation for north.*
- std::vector  
< [CoefficientFunction2D](#) > [west\\_coefficients\\_](#)  
*Coeffs. west.*
- std::vector  
< [CoefficientFunction2D](#) > [east\\_coefficients\\_](#)  
*Coeffs. east.*
- std::vector  
< [CoefficientFunction2D](#) > [south\\_coefficients\\_](#)  
*Coeffs. south.*
- std::vector  
< [CoefficientFunction2D](#) > [north\\_coefficients\\_](#)  
*Coeffs. south.*
- [Real](#)(\* [west\\_condition\\_](#))([Real](#) xx, [Real](#) yy)  
*Condition for west.*
- [Real](#)(\* [east\\_condition\\_](#))([Real](#) xx, [Real](#) yy)  
*Condition for east.*
- [Real](#)(\* [south\\_condition\\_](#))([Real](#) xx, [Real](#) yy)  
*Condition for south.*
- [Real](#)(\* [north\\_condition\\_](#))([Real](#) xx, [Real](#) yy)  
*Condition for north.*

### 16.2.1 Detailed Description

This class presents an interface for the user to specify boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let  $f$  be any scalar or vector field defined over a domain  $\Omega$ . We can specify any linear combination of  $f$  and its  $n$  derivatives to fulfill a condition, which we define as a **boundary condition**:

$$\forall \mathbf{x} \in \partial\Omega : \sum_{i=0}^n c_i(\mathbf{x}) < \hat{\mathbf{n}}, \frac{\partial^i f}{\partial x^i}(\mathbf{x}) > = \beta(\mathbf{x}).$$

This class receives information about the highest-order of differentiation,  $n$ , all possible coefficient functions,  $c_i(\mathbf{x})$  for any subset of the boundary (south, north, west and east), and each condition for any subset of the boundary, and takes care of assigning them to both, the differentiation matrices and the grids.

Definition at line 123 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

## 16.2.2 Constructor & Destructor Documentation

### 16.2.2.1 mtk::BCDescriptor2D::BCDescriptor2D ( )

Definition at line 80 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

### 16.2.2.2 mtk::BCDescriptor2D::BCDescriptor2D ( const BCDescriptor2D & desc )

#### Parameters

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

Definition at line 91 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

### 16.2.2.3 mtk::BCDescriptor2D::~BCDescriptor2D ( ) [noexcept]

Definition at line 93 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

## 16.2.3 Member Function Documentation

### 16.2.3.1 int mtk::BCDescriptor2D::highest\_order\_diff\_east ( ) const [noexcept]

#### Returns

Integer highest order of differentiation in the east boundary.

Definition at line 100 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

### 16.2.3.2 int mtk::BCDescriptor2D::highest\_order\_diff\_north ( ) const [noexcept]

#### Returns

Integer highest order of differentiation in the north boundary.

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

### 16.2.3.3 int mtk::BCDescriptor2D::highest\_order\_diff\_south ( ) const [noexcept]

#### Returns

Integer highest order of differentiation in the south boundary.

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

### 16.2.3.4 int mtk::BCDescriptor2D::highest\_order\_diff\_west ( ) const [noexcept]

#### Returns

Integer highest order of differentiation in the west boundary.

Definition at line 95 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

16.2.3.5 void mtk::BCDescriptor2D::ImposeOnEastBoundary ( const mtk::UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*,  
const int & *order\_accuracy* ) const [private]



## Parameters

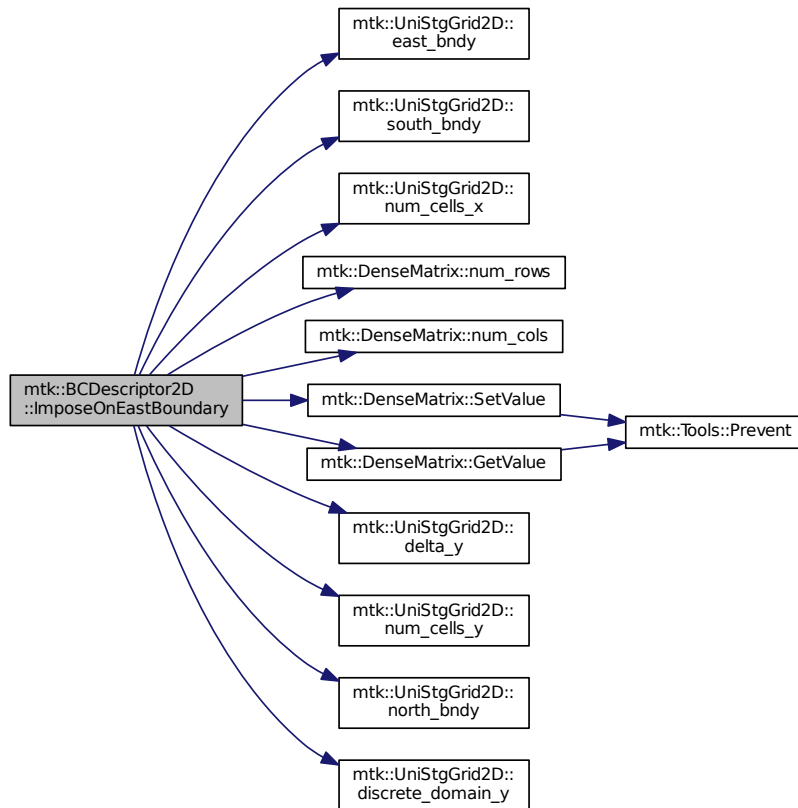
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input Laplacian operator.
in	<i>order_accuracy</i>	Order of accuracy of the operator in the <a href="#">Matrix</a> .

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

Definition at line 450 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



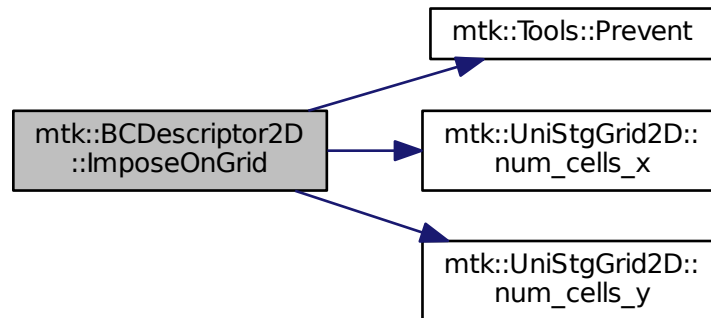
16.2.3.6 `void mtk::BCDescriptor2D::ImposeOnGrid ( mtk::UniStgGrid2D & grid ) const`

## Parameters

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

Definition at line 580 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



16.2.3.7 void mtk::BCDescriptor2D::ImposeOnLaplacianMatrix ( const UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const int & *order\_accuracy* = 2 ) const

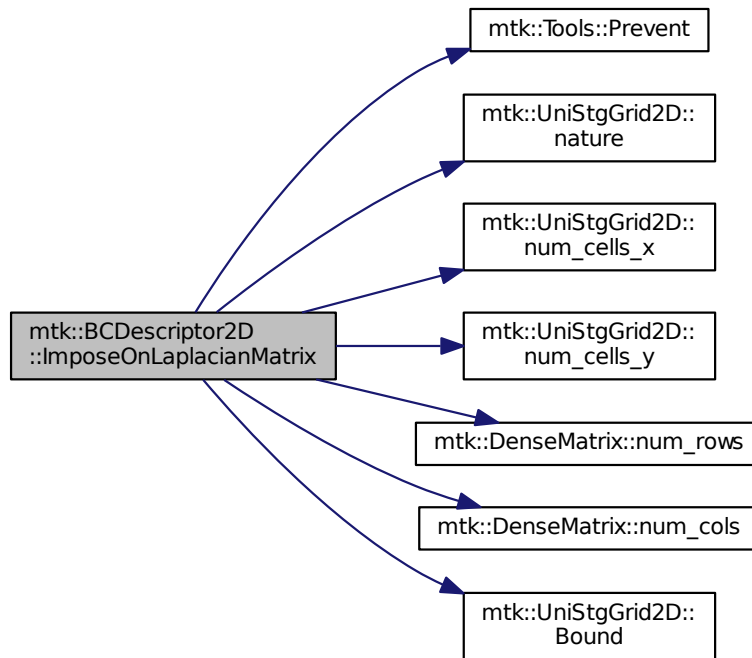
## Parameters

<i>in</i>	<i>grid</i>	Grid upon which impose the desired boundary condition.
<i>in, out</i>	<i>matrix</i>	Input Laplacian operator.
<i>in</i>	<i>order_accuracy</i>	Order of accuracy of the operator in the <a href="#">Matrix</a> .

1. If we have not bound anything to the grid, then we have to generate our collection of spatial coordinates, as we evaluate the coefficients.
2. Assign values to implement south boundary condition.
3. Assign values to implement north boundary condition.
4. Assign values to implement west boundary condition.
5. Assign values to implement east boundary condition.

Definition at line 536 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



**16.2.3.8** `void mtk::BCDescriptor2D::ImposeOnNorthBoundary ( const mtk::UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const int & order_accuracy ) const` `[private]`

#### Parameters

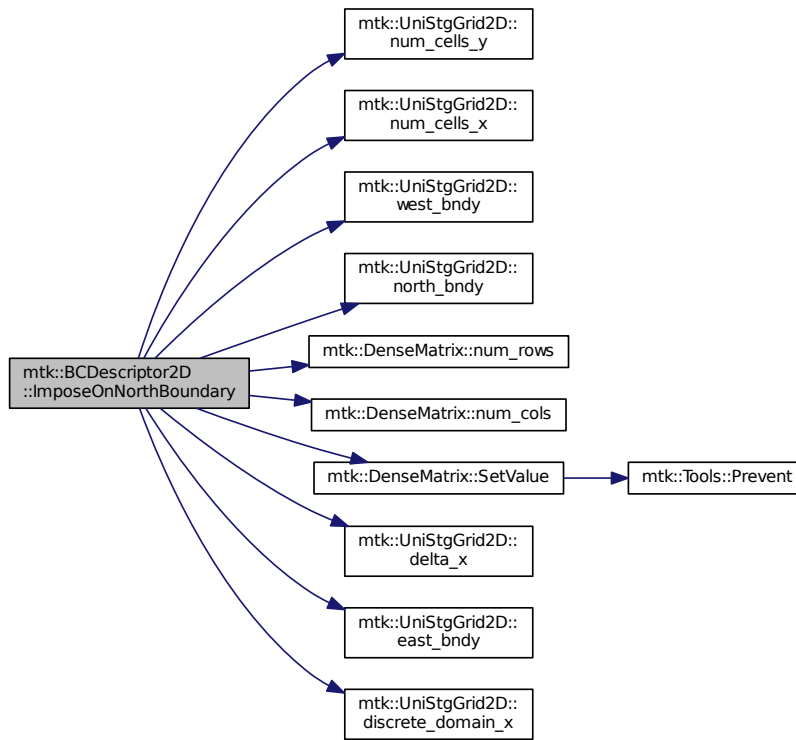
in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input Laplacian operator.
in	<i>order_accuracy</i>	Order of accuracy of the operator in the <a href="#">Matrix</a> .

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

Definition at line [286](#) of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



16.2.3.9 void mtk::BCDescriptor2D::ImposeOnSouthBoundary ( const mtk::UniStgGrid2D & *grid*, mtk::DenseMatrix & *matrix*, const int & *order\_accuracy* ) const [private]

#### Parameters

in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input Laplacian operator.
in	<i>order_accuracy</i>	Order of accuracy of the operator in the <a href="#">Matrix</a> .

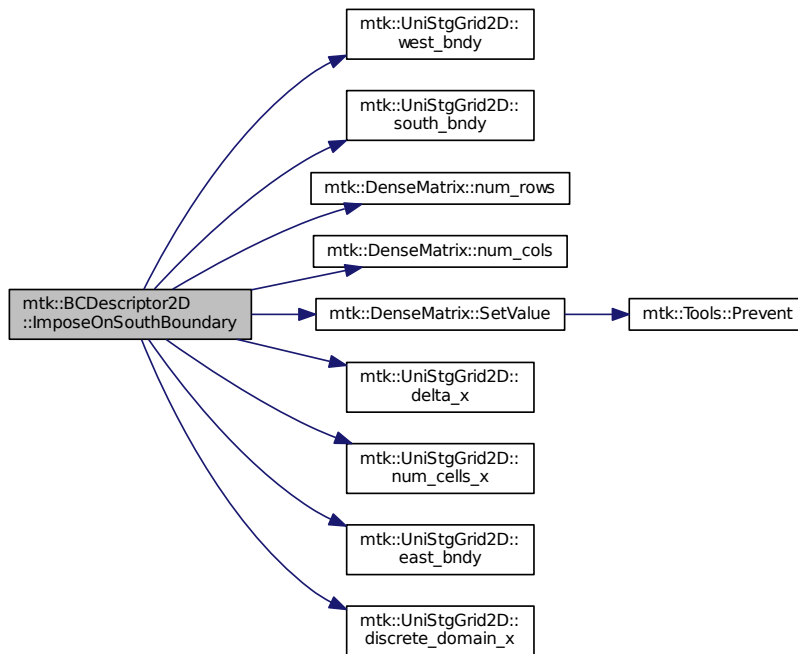
1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

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

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

Definition at line 209 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



**16.2.3.10** `void mtk::BCDescriptor2D::ImposeOnWestBoundary ( const mtk::UniStgGrid2D & grid, mtk::DenseMatrix & matrix, const int & order_accuracy ) const [private]`

#### Parameters

in	<i>grid</i>	Grid upon which impose the desired boundary condition.
in, out	<i>matrix</i>	Input Laplacian operator.
in	<i>order_accuracy</i>	Order of accuracy of the operator in the <a href="#">Matrix</a> .

1. Impose the Dirichlet condition first.

#### Note

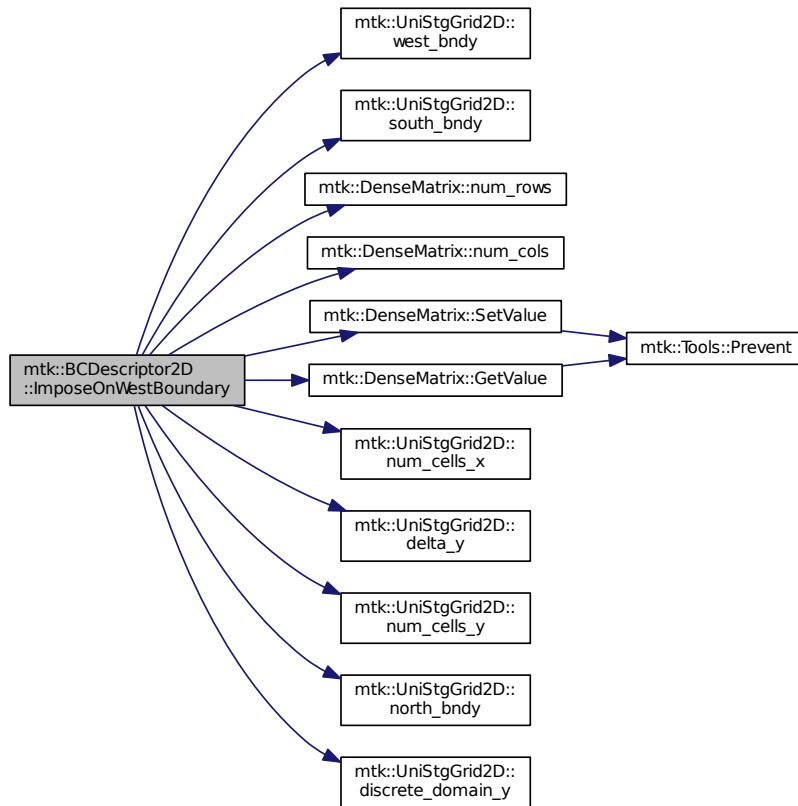
As it can be seen, we must adopt a convention about how to treat the corners. Based on a reasoning with Otilio, we will take the arithmetic mean.

1. Impose the Neumann condition second.

1. Impose the Dirichlet condition first.
2. Impose the Neumann condition second.

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

Here is the call graph for this function:



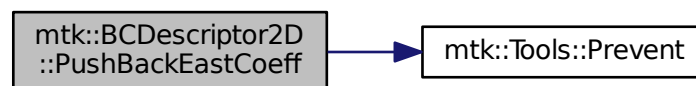
16.2.3.11 `void mtk::BCDescriptor2D::PushBackEastCoeff ( mtk::CoefficientFunction2D ce )`

Parameters

<code>in</code>	<code>ce</code>	Function $c_e(x, y) : \Omega \mapsto \mathbb{R}$ .
-----------------	-----------------	--

Definition at line 128 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



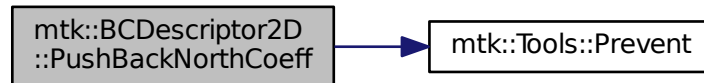
16.2.3.12 void mtk::BCDescriptor2D::PushBackNorthCoeff ( mtk::CoefficientFunction2D *cn* )

## Parameters

in	<i>cn</i>	Function $c_n(x, y) : \Omega \mapsto \mathbb{R}$ .
----	-----------	--

Definition at line 154 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:

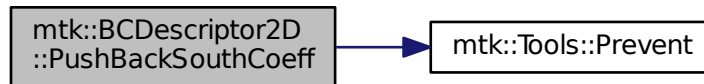
16.2.3.13 void mtk::BCDescriptor2D::PushBackSouthCoeff ( mtk::CoefficientFunction2D *cs* )

## Parameters

in	<i>cs</i>	Function $c_s(x, y) : \Omega \mapsto \mathbb{R}$ .
----	-----------	--

Definition at line 141 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:

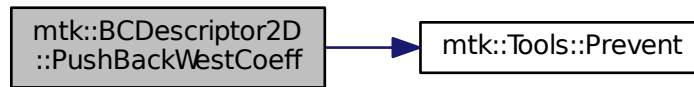
16.2.3.14 void mtk::BCDescriptor2D::PushBackWestCoeff ( mtk::CoefficientFunction2D *cw* )

## Parameters

in	<i>cw</i>	Function $c_w(x, y) : \Omega \mapsto \mathbb{R}$ .
----	-----------	--

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

Here is the call graph for this function:



16.2.3.15 `void mtk::BCDescriptor2D::set_east_condition ( Real(*) (Real xx, Real yy) east_condition ) [noexcept]`

#### Parameters

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

Definition at line 177 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



16.2.3.16 `void mtk::BCDescriptor2D::set_north_condition ( Real(*) (Real xx, Real yy) north_condition ) [noexcept]`

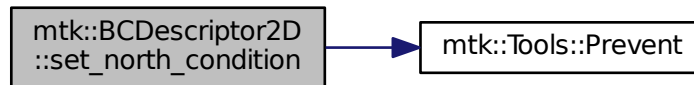
#### Parameters

<code>in</code>	<code>north_condition</code>	$\beta_n(x, y) : \Omega \mapsto \mathbb{R}.$
-----------------	------------------------------	--

Definition at line 198 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).



Here is the call graph for this function:



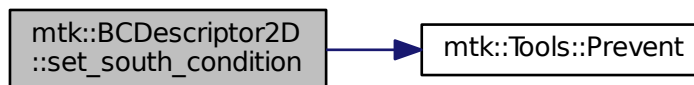
16.2.3.17 void mtk::BCDescriptor2D::set\_south\_condition ( Real(\*) (Real xx, Real yy) *south\_condition* ) [noexcept]

#### Parameters

in	<i>south_condition</i>	$\beta_s(x, y) : \Omega \mapsto \mathbb{R}.$
----	------------------------	--

Definition at line 187 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



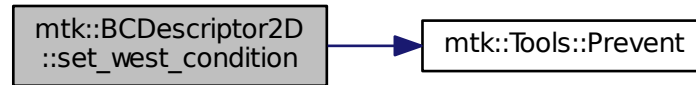
16.2.3.18 void mtk::BCDescriptor2D::set\_west\_condition ( Real(\*) (Real xx, Real yy) *west\_condition* ) [noexcept]

#### Parameters

in	<i>west_condition</i>	$\beta_w(x, y) : \Omega \mapsto \mathbb{R}.$
----	-----------------------	--

Definition at line 167 of file [mtk\\_bc\\_descriptor\\_2d.cc](#).

Here is the call graph for this function:



## 16.2.4 Member Data Documentation

16.2.4.1 `std::vector<CoefficientFunction2D> mtk::BCDescriptor2D::east_coefficients_` [private]

Definition at line 293 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.2 `Real(* mtk::BCDescriptor2D::east_condition_)(Real xx, Real yy)` [private]

Definition at line 298 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.3 `bool mtk::BCDescriptor2D::generate_space_` [mutable], [private]

Definition at line 285 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.4 `int mtk::BCDescriptor2D::highest_order_diff_east_` [private]

Definition at line 288 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.5 `int mtk::BCDescriptor2D::highest_order_diff_north_` [private]

Definition at line 290 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.6 `int mtk::BCDescriptor2D::highest_order_diff_south_` [private]

Definition at line 289 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.7 `int mtk::BCDescriptor2D::highest_order_diff_west_` [private]

Definition at line 287 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.8 `std::vector<CoefficientFunction2D> mtk::BCDescriptor2D::north_coefficients_` [private]

Definition at line 295 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.9 `Real(* mtk::BCDescriptor2D::north_condition_)(Real xx, Real yy)` [private]

Definition at line 300 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.10 `std::vector<CoefficientFunction2D> mtk::BCDescriptor2D::south_coefficients_` [private]

Definition at line 294 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.11 `Real(* mtk::BCDescriptor2D::south_condition_)(Real xx, Real yy)` [private]

Definition at line 299 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.12 `std::vector<CoefficientFunction2D> mtk::BCDescriptor2D::west_coefficients_` [private]

Definition at line 292 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

16.2.4.13 `Real(* mtk::BCDescriptor2D::west_condition_)(Real xx, Real yy)` [private]

Definition at line 297 of file [mtk\\_bc\\_descriptor\\_2d.h](#).

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

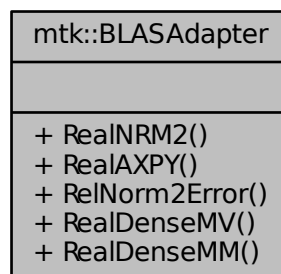
- [include/mtk\\_bc\\_descriptor\\_2d.h](#)
- [src/mtk\\_bc\\_descriptor\\_2d.cc](#)

## 16.3 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.*

### 16.3.1 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](#).

### 16.3.2 Member Function Documentation

16.3.2.1 void [mtk::BLASAdapter::RealAXPY](#) ( [mtk::Real](#) alpha, [mtk::Real](#) \* xx, [mtk::Real](#) \* yy, int & in\_length )  
[static]

Performs

$$y := \alpha A x + y$$

Parameters

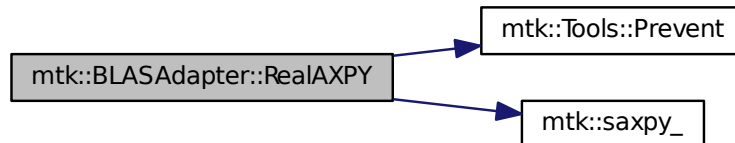
in	alpha	Scalar of the first array.
in	xx	First array.
in	yy	Second array.
in	in_length	Lengths of the given arrays.

**Returns**

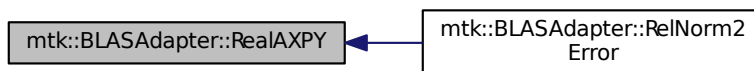
Norm-2 of the given array.

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:



**16.3.2.2** `mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM ( mtk::DenseMatrix & aa, mtk::DenseMatrix & bb )`  
`[static]`

Performs:

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

**Parameters**

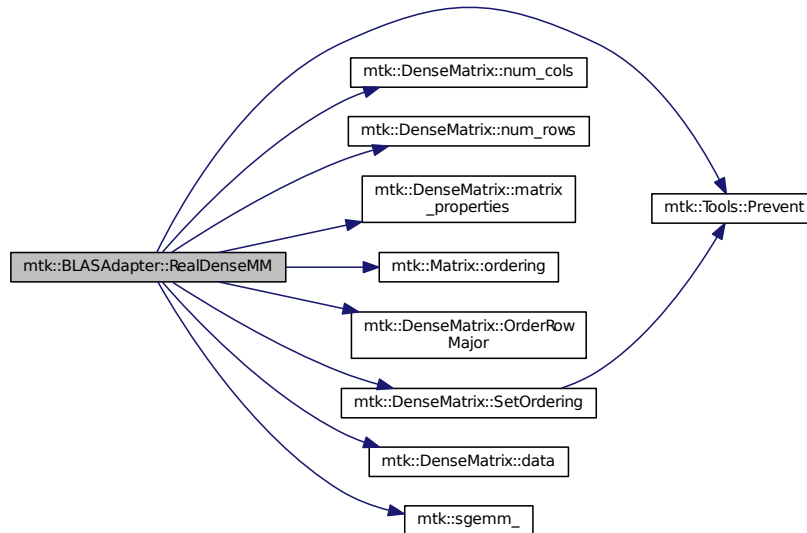
in	<i>aa</i>	First matrix.
in	<i>bb</i>	Second matrix.

See also

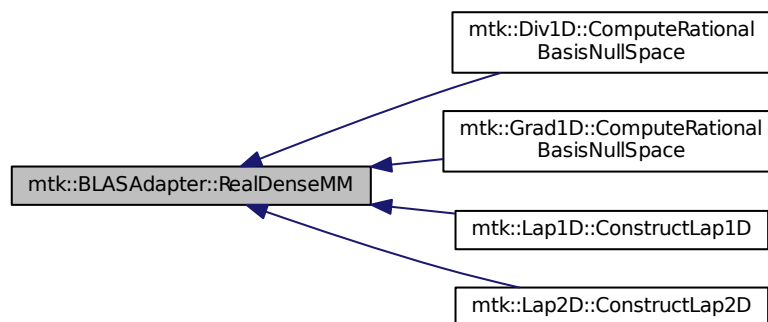
<http://ejspeiro.github.io/Netlib-and-CPP/>

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:



16.3.2.3 `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**

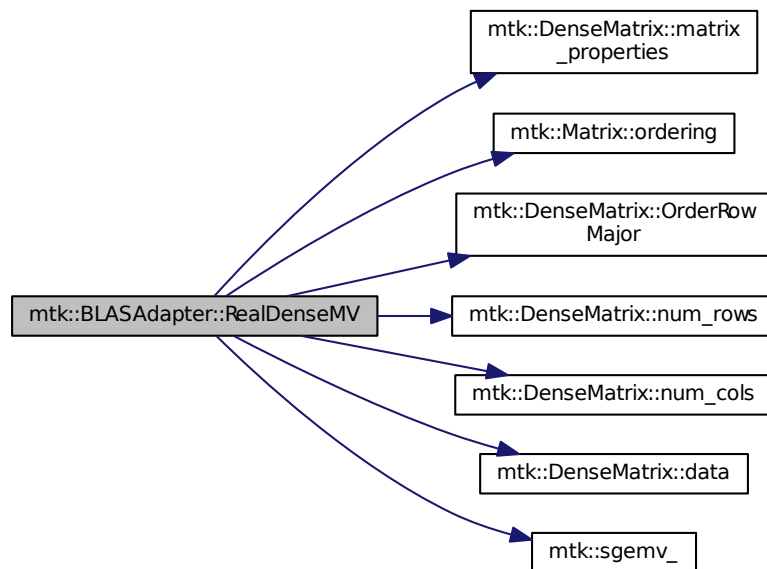
in	<i>alpha</i>	First scalar.
in	<i>aa</i>	Given matrix.
in	<i>xx</i>	First vector.
in	<i>beta</i>	Second scalar.
in, out	<i>yy</i>	Second vector (output).

**See also**

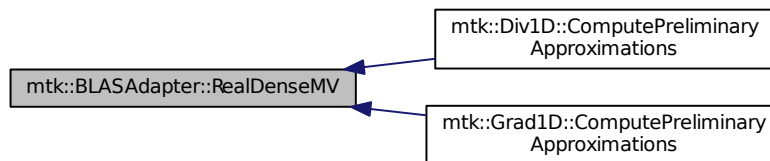
<http://ejspeiro.github.io/Netlib-and-CPP/>

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:



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

##### Parameters

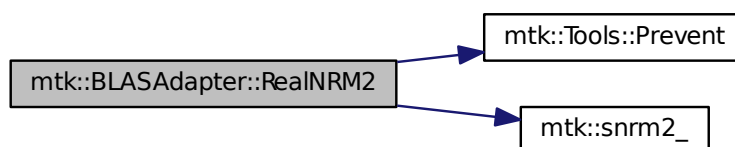
<code>in</code>	<code>in</code>	Input array.
<code>in</code>	<code>in_length</code>	Length of the array.

##### Returns

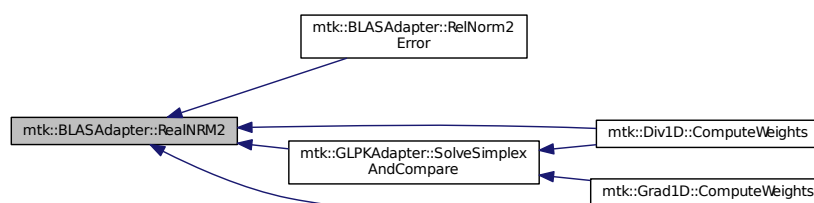
Norm-2 of the given array.

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:





16.3.2.5 `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

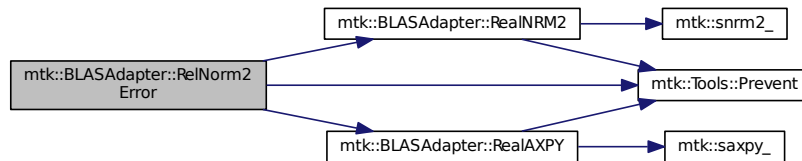
in	<i>known</i>	Array containing the computed solution.
in	<i>computed</i>	Array containing the known solution (ref. solution).

#### 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:

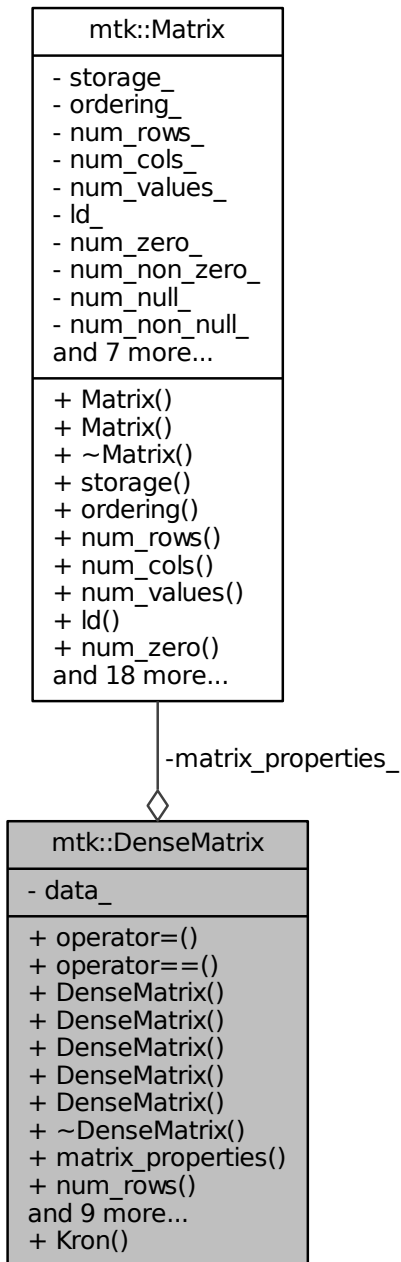
- [include/mtk\\_blas\\_adapter.h](#)
- [src/mtk\\_blas\\_adapter.cc](#)

## 16.4 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).*

### 16.4.1 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.

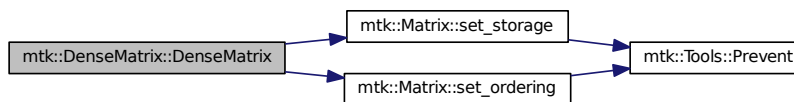
Definition at line 92 of file [mtk\\_dense\\_matrix.h](#).

### 16.4.2 Constructor & Destructor Documentation

#### 16.4.2.1 `mtk::DenseMatrix::DenseMatrix ( )`

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

Here is the call graph for this function:



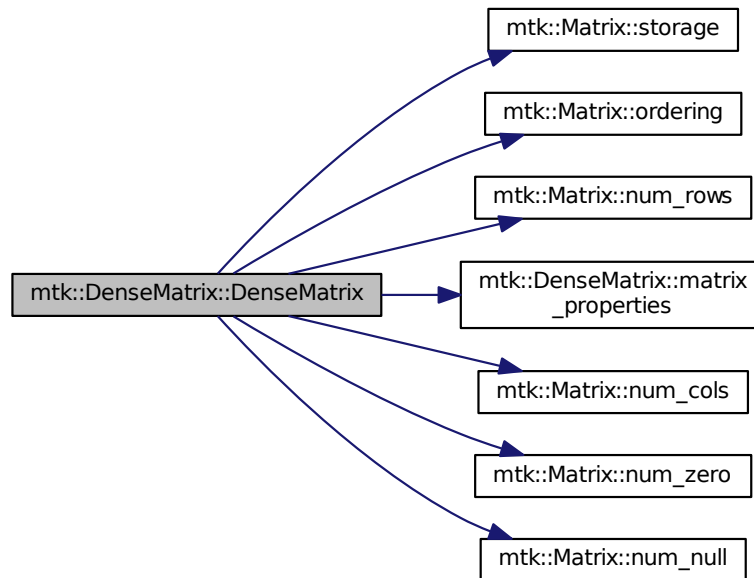
#### 16.4.2.2 `mtk::DenseMatrix::DenseMatrix ( const DenseMatrix &in )`

##### 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:



#### 16.4.2.3 mtk::DenseMatrix::DenseMatrix ( const int & *num\_rows*, const int & *num\_cols* )

##### Parameters

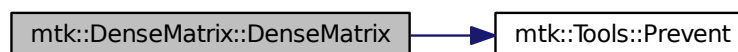
in	<i>num_rows</i>	Number of rows of the required matrix.
in	<i>num_cols</i>	Number of rows of the required matrix.

##### Exceptions

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

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

Here is the call graph for this function:



#### 16.4.2.4 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

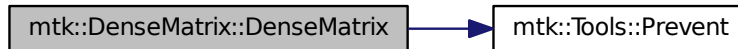
in	<i>rank</i>	Rank or number of rows/cols in square matrix.
in	<i>padded</i>	Should it be padded?
in	<i>transpose</i>	Should I return the transpose of the requested matrix?

##### Exceptions

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

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

Here is the call graph for this function:



#### 16.4.2.5 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

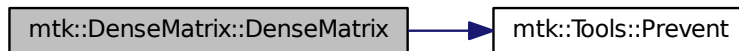
in	<i>gen</i>	Given generator vector.
in	<i>gen_length</i>	Length generator vector.
in	<i>pro_length</i>	Length the progression.
in	<i>transpose</i>	Should the transpose be created instead?

## Exceptions

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

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

Here is the call graph for this function:



## 16.4.2.6 mtk::DenseMatrix::~~DenseMatrix ( )

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

## 16.4.3 Member Function Documentation

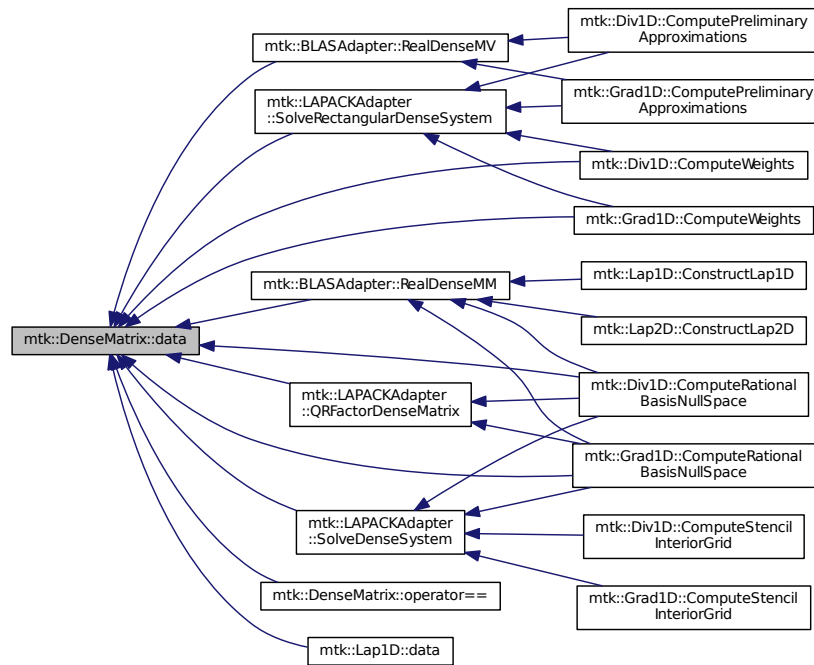
## 16.4.3.1 mtk::Real \* mtk::DenseMatrix::data ( ) const [noexcept]

## 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:



#### 16.4.3.2 `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.

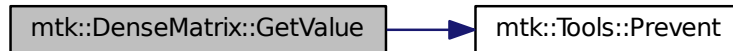


**Returns**

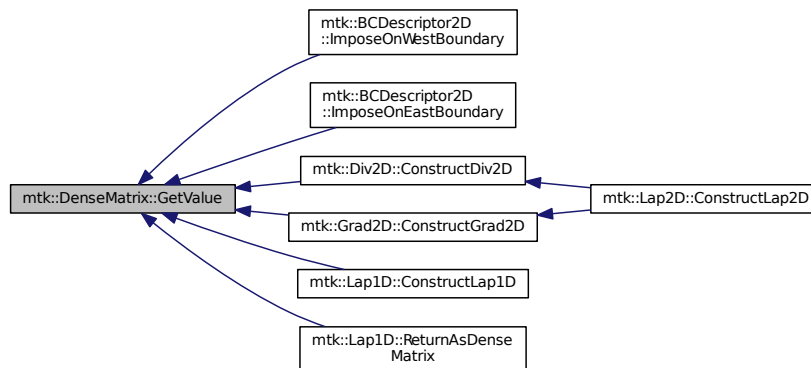
The required value at the specified coordinates.

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:



### 16.4.3.3 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.

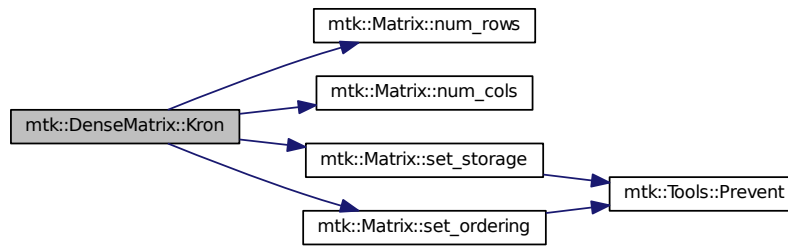
**Exceptions**

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

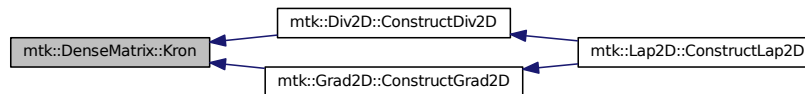
**Todo** Implement Kronecker product using the BLAS.

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:



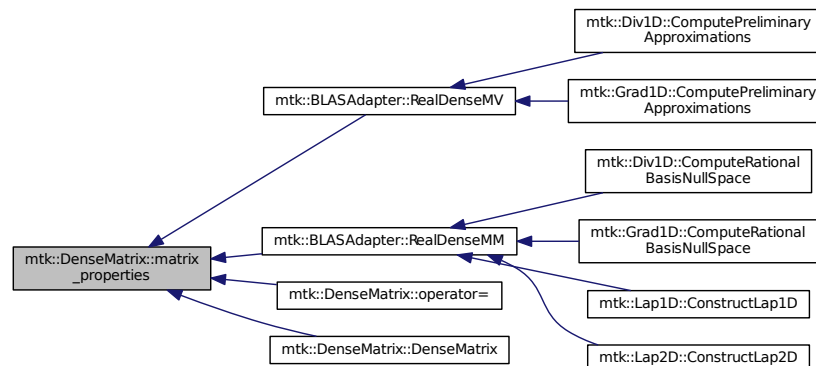
#### 16.4.3.4 `mtk::Matrix mtk::DenseMatrix::matrix_properties ( ) const [noexcept]`

Returns

Pointer to a [Matrix](#).

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

Here is the caller graph for this function:



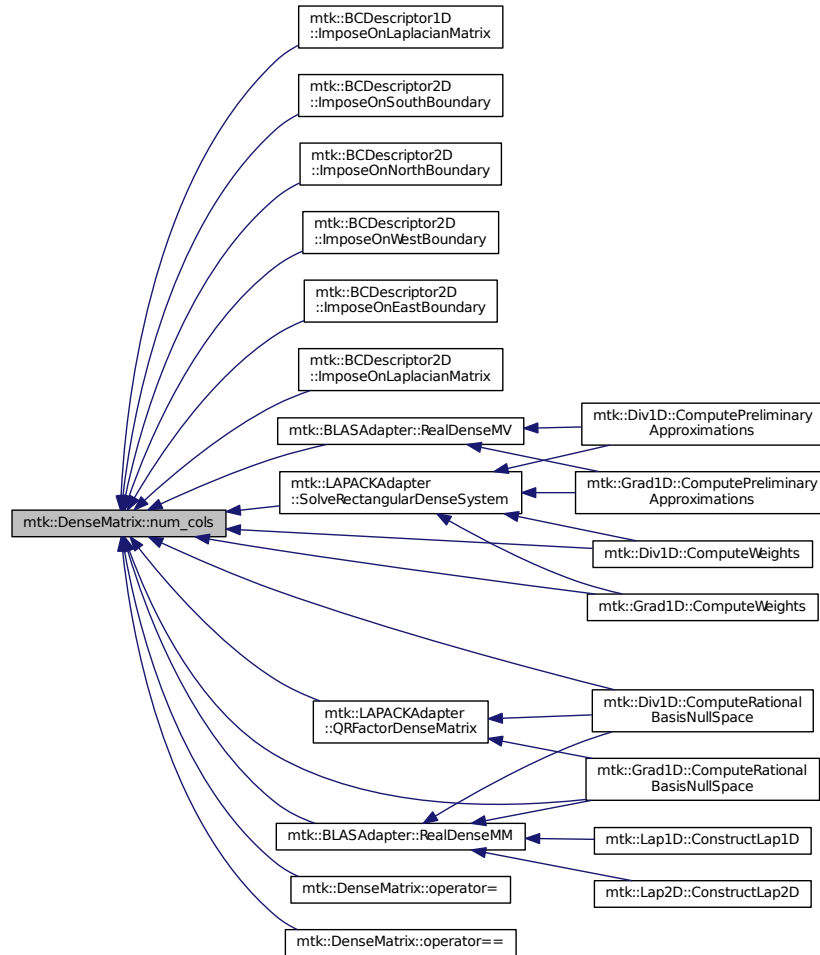
16.4.3.5 `int mtk::DenseMatrix::num_cols ( ) const [noexcept]`

#### 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:



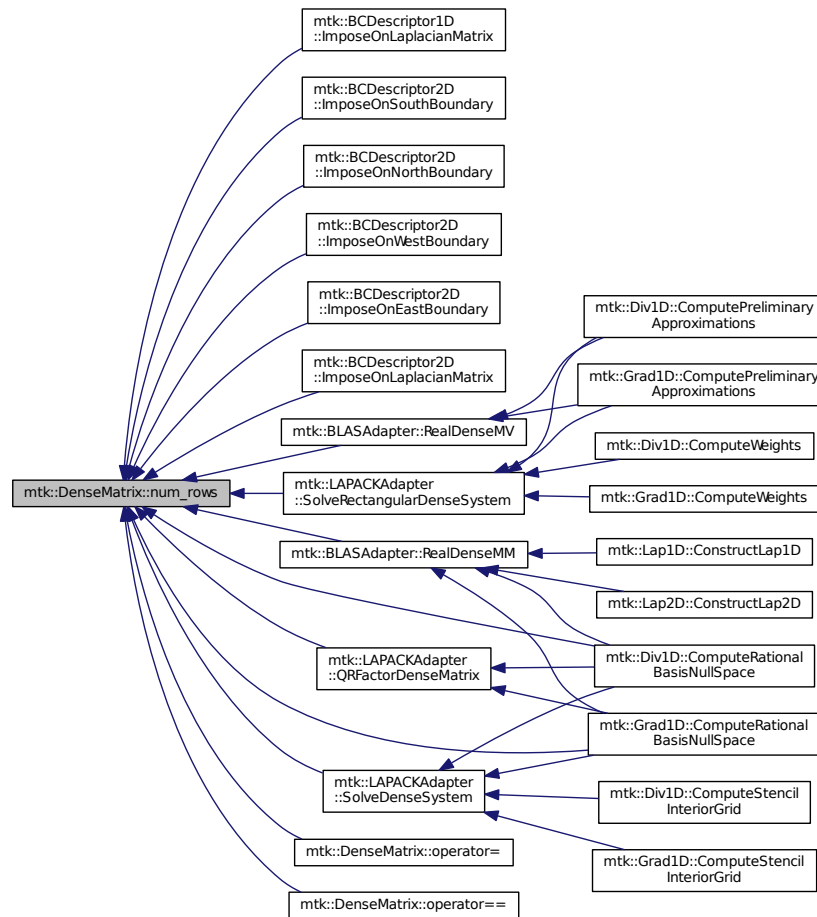
16.4.3.6 `int mtk::DenseMatrix::num_rows ( ) const [noexcept]`

## Returns

Number of rows of the matrix.

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

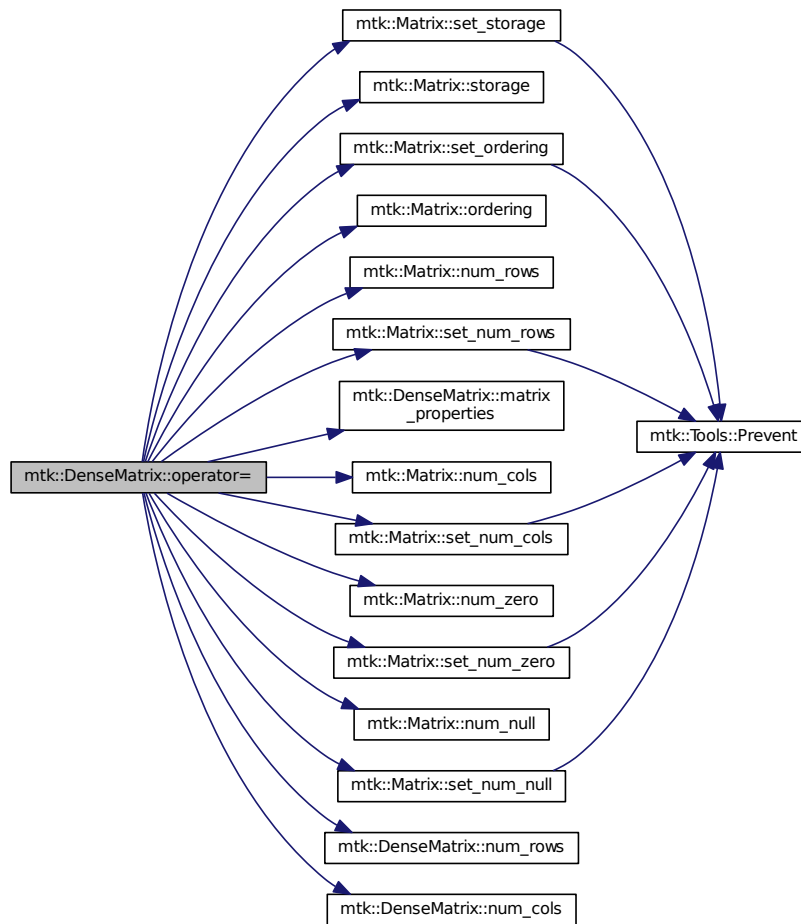
Here is the caller graph for this function:



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

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

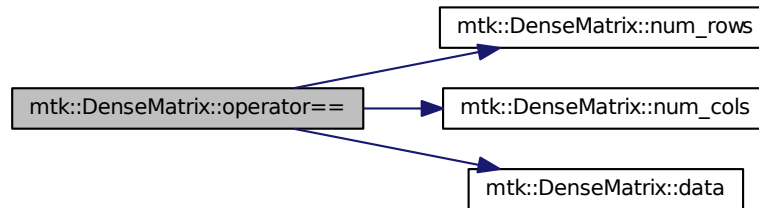
Here is the call graph for this function:



#### 16.4.3.8 `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:

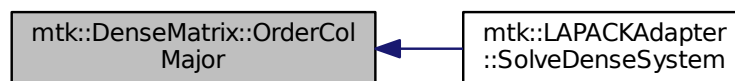


16.4.3.9 `void mtk::DenseMatrix::OrderColMajor ( )`

**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:

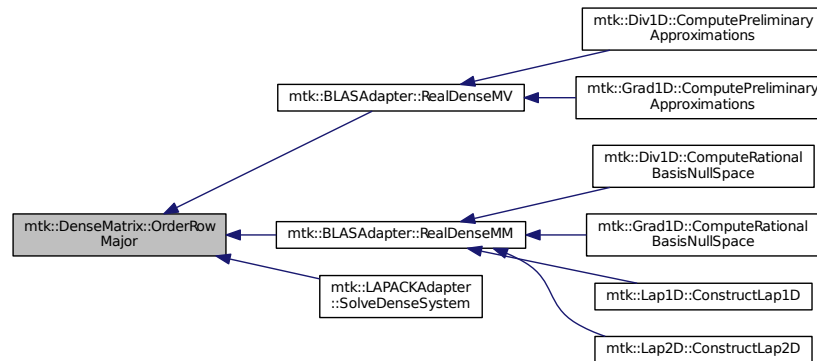


16.4.3.10 `void mtk::DenseMatrix::OrderRowMajor ( )`

**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:



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

#### Parameters

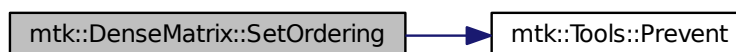
in	oo	Ordering.
----	----	-----------

#### Returns

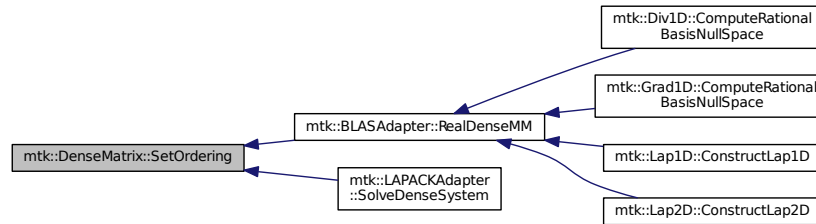
The required value at the specified coordinates.

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:



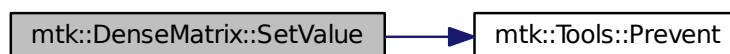
16.4.3.12 void mtk::DenseMatrix::SetValue ( const int & row\_coord, const int & col\_coord, const Real & val ) [noexcept]

#### 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.

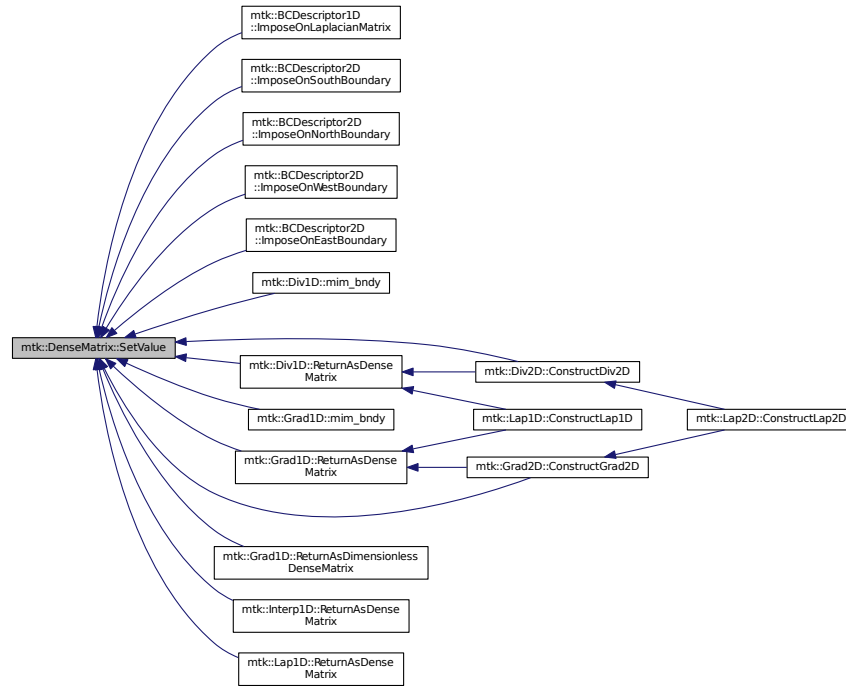
Definition at line 360 of file [mtk\\_dense\\_matrix.cc](#).

Here is the call graph for this function:





Here is the caller graph for this function:

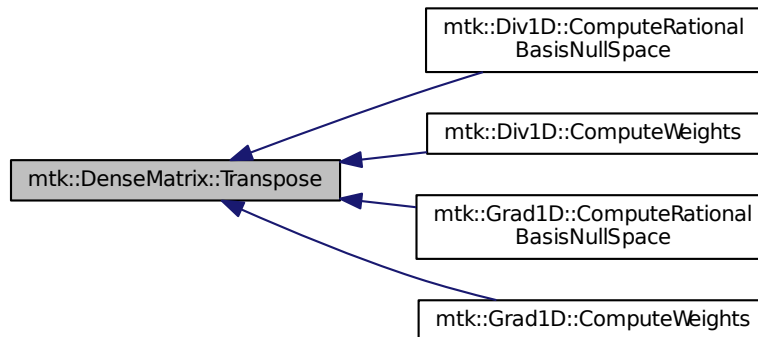


#### 16.4.3.13 void mtk::DenseMatrix::Transpose ( )

**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:



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

#### Parameters

<code>in</code>	<code><i>filename</i></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](#).

### 16.4.4 Friends And Related Function Documentation

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

Definition at line 77 of file [mtk\\_dense\\_matrix.cc](#).

### 16.4.5 Member Data Documentation

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

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

16.4.5.2 `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:

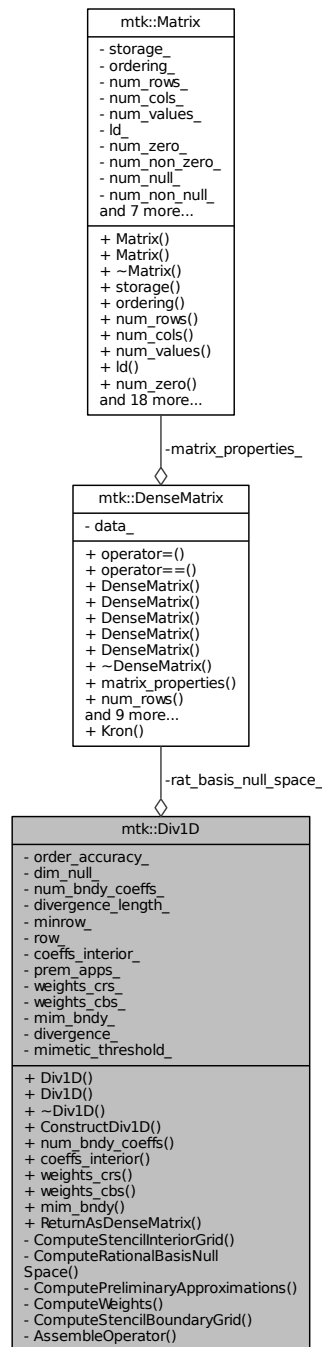
- [include/mtk\\_dense\\_matrix.h](#)
- [src/mtk\\_dense\\_matrix.cc](#)

## 16.5 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.*

### 16.5.1 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`.

### 16.5.2 Constructor & Destructor Documentation

#### 16.5.2.1 `mtk::Div1D::Div1D ( )`

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

#### 16.5.2.2 `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`.

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

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

### 16.5.3 Member Function Documentation

#### 16.5.3.1 `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 [1334](#) of file [mtk\\_div\\_1d.cc](#).

#### 16.5.3.2 `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](#).

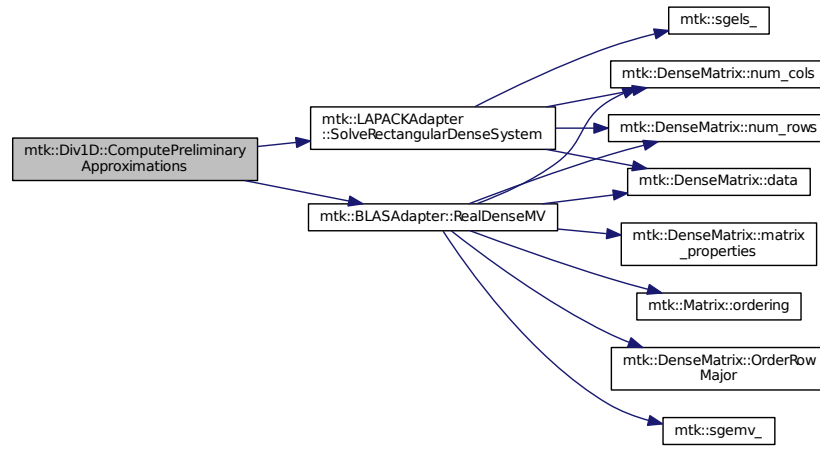
#### 16.5.3.3 `bool mtk::Div1D::ComputePreliminaryApproximations ( void ) [private]`

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 [689](#) of file [mtk\\_div\\_1d.cc](#).

Here is the call graph for this function:



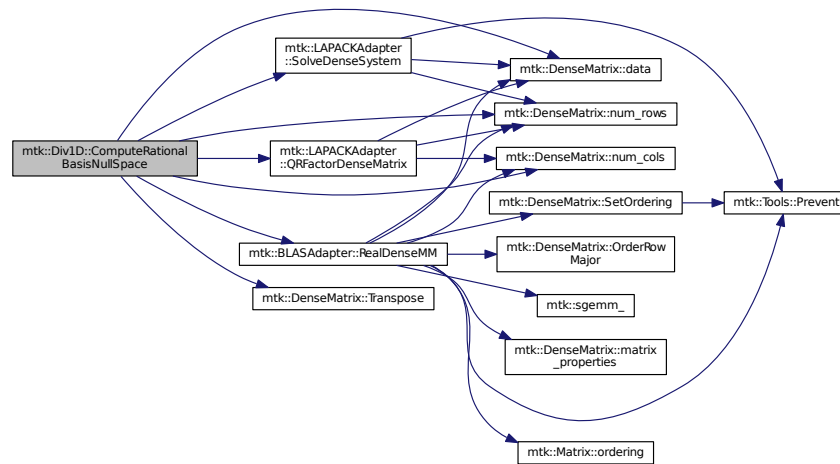
#### 16.5.3.4 `bool mtk::Div1D::ComputeRationalBasisNullSpace ( void ) [private]`

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 513 of file `mtk_div_1d.cc`.

Here is the call graph for this function:



#### 16.5.3.5 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 1235 of file [mtk\\_div\\_1d.cc](#).

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

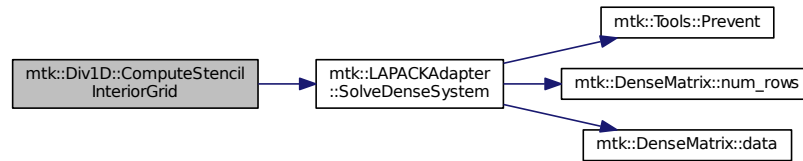
Compute the stencil approximating the interior of the staggered grid.

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:



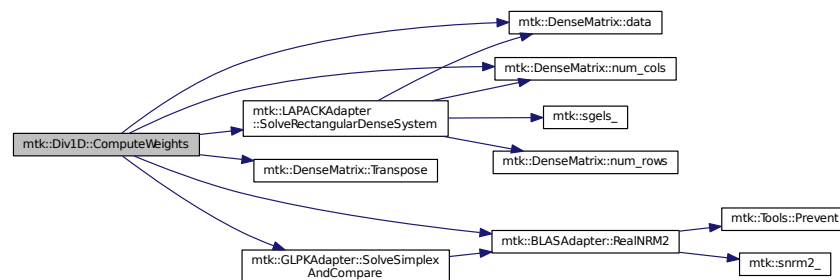
### 16.5.3.7 bool mtk::Div1D::ComputeWeights ( void ) [private]

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 909 of file [mtk\\_div\\_1d.cc](#).

Here is the call graph for this function:



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

#### Returns

Success of the construction.

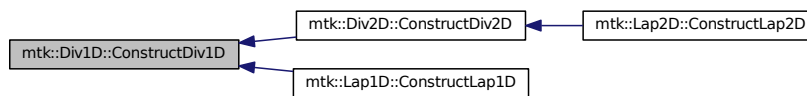
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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



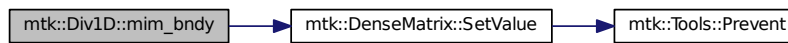
16.5.3.9 `mtk::DenseMatrix mtk::Div1D::mim_bndy ( ) const`

**Returns**

Collection of mimetic approximations at the boundary.

Definition at line 336 of file [mtk\\_div\\_1d.cc](#).

Here is the call graph for this function:



### 16.5.3.10 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](#).

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

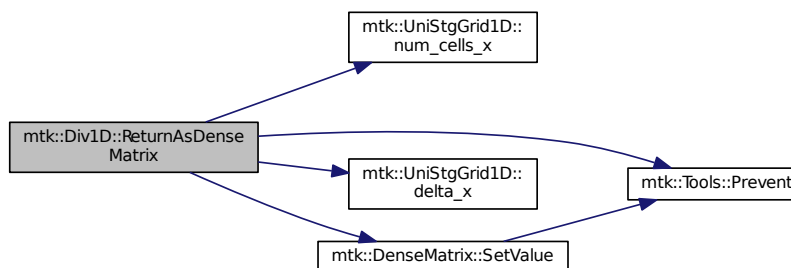
**Returns**

The operator as a dense matrix.

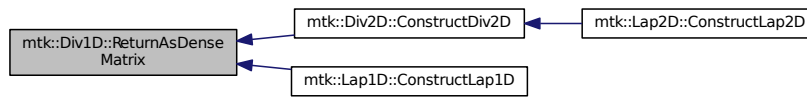
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 351 of file [mtk\\_div\\_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



#### 16.5.3.12 `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](#).

#### 16.5.3.13 `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](#).

### 16.5.4 Friends And Related Function Documentation

#### 16.5.4.1 `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](#).

### 16.5.5 Member Data Documentation

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

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

#### 16.5.5.2 `int mtk::Div1D::dim_null_ [private]`

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

16.5.5.14 **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](#)

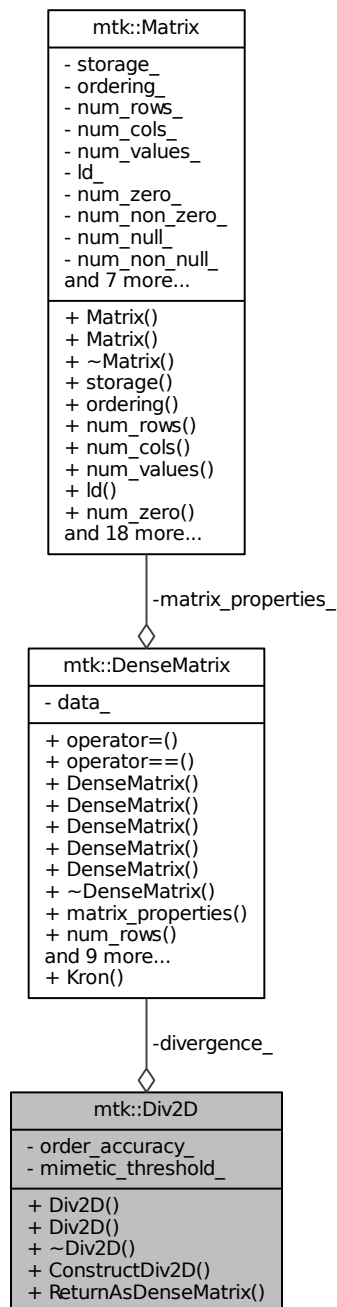
- [src/mtk\\_div\\_1d.cc](#)

## 16.6 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.*

## 16.6.1 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](#).

## 16.6.2 Constructor & Destructor Documentation

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

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

### 16.6.2.2 [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](#).

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

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



### 16.6.3 Member Function Documentation

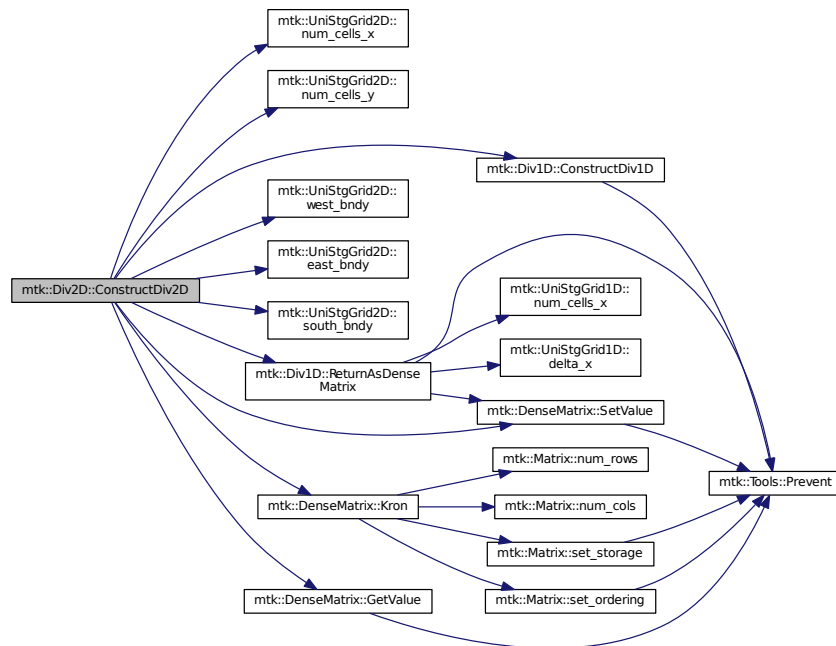
16.6.3.1 `bool mtk::Div2D::ConstructDiv2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### 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:



16.6.3.2 `mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix ( ) const`

**Returns**

The operator as a dense matrix.

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

Here is the caller graph for this function:

**16.6.4 Member Data Documentation****16.6.4.1 DenseMatrix mtk::Div2D::divergence\_ [private]**

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

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

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

**16.6.4.3 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:

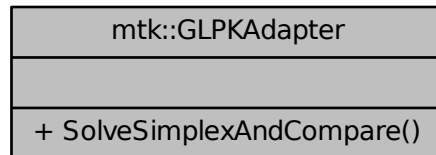
- [include/mtk\\_div\\_2d.h](#)
- [src/mtk\\_div\\_2d.cc](#)

**16.7 mtk::GLPKAdapter Class Reference**

Adapter class for the GLPK API.

```
#include <mtk_glpk_adapter.h>
```

Collaboration diagram for mtk::GLPKAdapter:



### Static Public Member Functions

- static `mtk::Real SolveSimplexAndCompare (mtk::Real *A, int nrows, int ncols, int kk, mtk::Real *hh, mtk::Real *qq, int robjective, mtk::Real mimetic_tol, int copy)`  
*Solves a CLO problem and compares the solution to a reference solution.*

#### 16.7.1 Detailed Description

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

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

#### Warning

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

#### See also

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

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

Definition at line 101 of file `mtk_glpk_adapter.h`.

#### 16.7.2 Member Function Documentation

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

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

**Parameters**

in	<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.

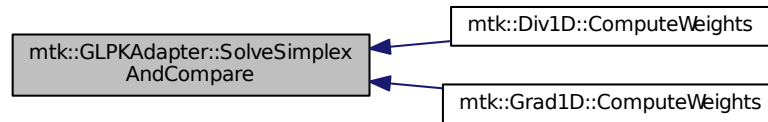
1. Memory allocation.
2. Fill the problem.
3. Copy the row to the vector objective.
4. Forming the RHS.
5. Setting up the objective function.
6. Setting up constraints.
7. Copy the matrix minus the row objective to the glpk problem.
8. Solve problem.

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:

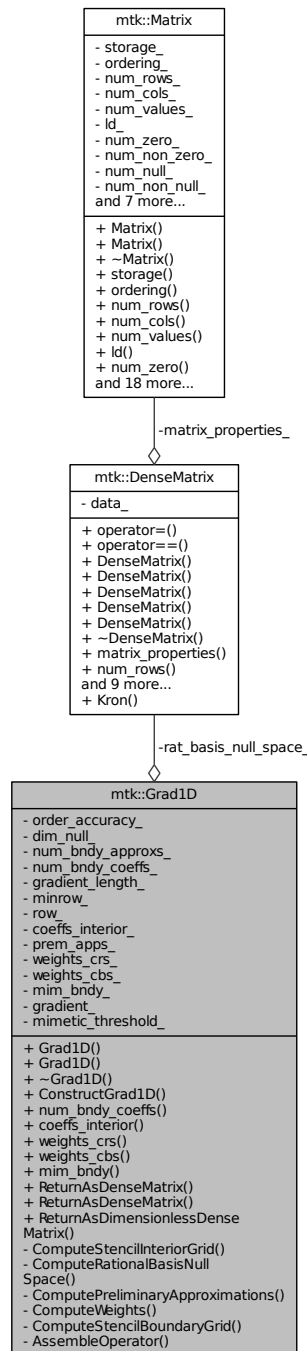
- [include/mtk\\_glpk\\_adapter.h](#)
- [src/mtk\\_glpk\\_adapter.cc](#)

## 16.8 mtk::Grad1D Class Reference

Implements a 1D mimetic gradient operator.

```
#include <mtk_grad_1d.h>
```

Collaboration diagram for mtk::Grad1D:



## Public Member Functions

- [Grad1D \(\)](#)

- Default constructor.*
- [Grad1D](#) (const [Grad1D](#) &grad)
- Copy constructor.*
- [~Grad1D](#) ()
- Destructor.*
- bool [ConstructGrad1D](#) (int order\_accuracy=[kDefaultOrderAccuracy](#), [Real](#) mimetic\_threshold=[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.*

## 16.8.1 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](#).

## 16.8.2 Constructor & Destructor Documentation

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

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

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



## Parameters

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

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

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

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

## 16.8.3 Member Function Documentation

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

Construct the output array with the operator and its weights.

1. The first entry of the array will contain the order of accuracy.
2. The second entry of the array will contain the collection of approximating coefficients for the interior of the grid.
3. The third entry will contain the collection of weights.
4. The next  $\text{dim\_null} + 1$  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](#).

## 16.8.3.2 mtk::Real \* mtk::Grad1D::coeffs\_interior ( ) const

## Returns

Coefficients for the interior of the grid.

Definition at line 330 of file [mtk\\_grad\\_1d.cc](#).

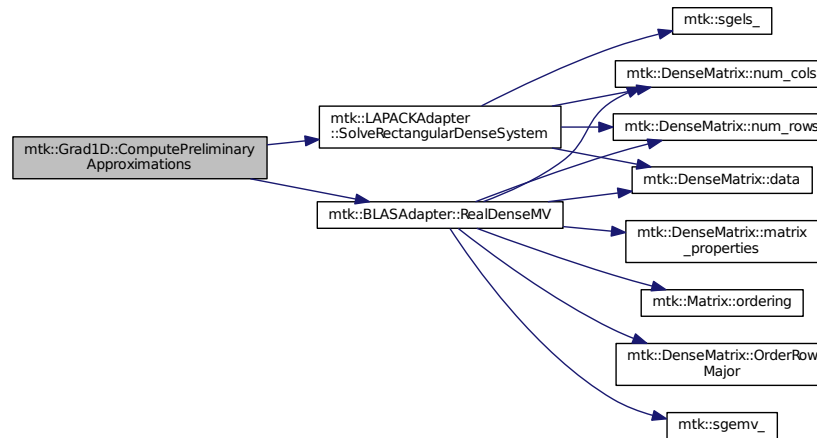
## 16.8.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations ( void ) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the  $\text{dim\_null}$  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 833 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



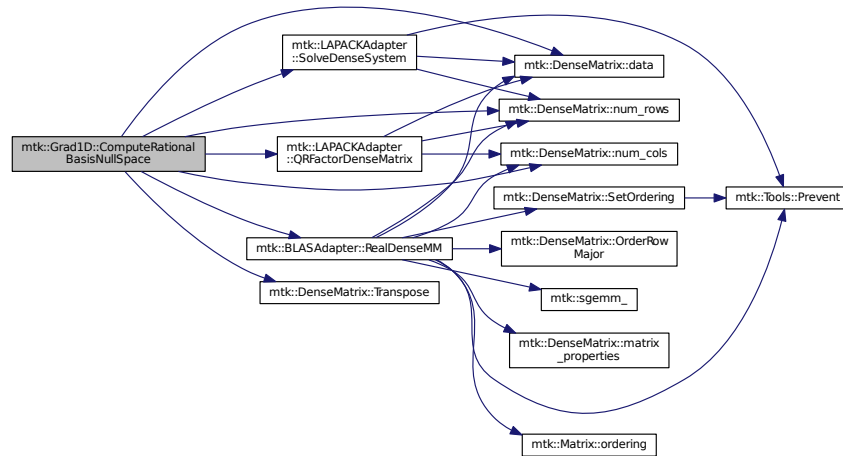
#### 16.8.3.4 `bool mtk::Grad1D::ComputeRationalBasisNullSpace ( void ) [private]`

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

1. Create generator vector for the first approximation.
2. Create Vandermonde matrix.
3. QR-factorize the Vandermonde matrix.
4. Extract the basis for the null-space from Q matrix.
5. Scale null-space to make it rational.

Definition at line 650 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



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

Compute mimetic stencil approximating at boundary.

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

Definition at line 1393 of file [mtk\\_grad\\_1d.cc](#).

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

Compute the stencil approximating the interior of the staggered grid.

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

Definition at line 554 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



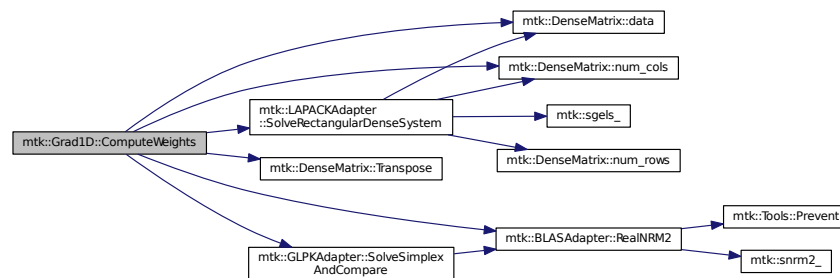
### 16.8.3.7 bool mtk::Grad1D::ComputeWeights ( void ) [private]

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

1. Construct the  $\mathbf{A}$  matrix.
2. Use interior stencil to build proper RHS vector  $\mathbf{h}$ .
3. Get weights (as **CRSA**):  $\mathbf{w} = \mathbf{h}$ .
4. If required order is greater than critical order, start the **CBSA**.
5. Create  $\mathbf{A}$  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 1053 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



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

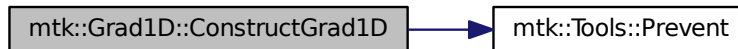
## Returns

Success of the solution.

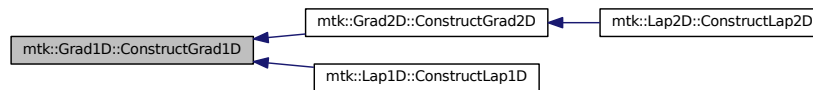
1. Compute stencil for the interior cells.
2. Compute a rational null-space from the first matrix transposed.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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

Definition at line 182 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



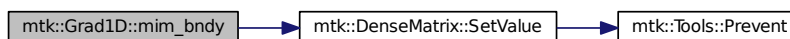
### 16.8.3.9 mtk::DenseMatrix mtk::Grad1D::mim\_bndy ( ) const

## Returns

Collection of mimetic approximations at the boundary.

Definition at line 345 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



### 16.8.3.10 int mtk::Grad1D::num\_bndy\_coeffs ( ) const

#### Returns

How many coefficients are approximating at the boundary.

Definition at line 325 of file [mtk\\_grad\\_1d.cc](#).

### 16.8.3.11 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix ( mtk::Real west, mtk::Real east, int num\_cells\_x ) const

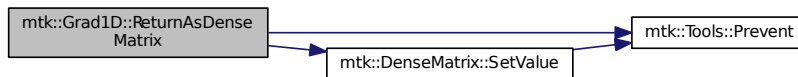
#### Returns

The operator as a dense matrix.

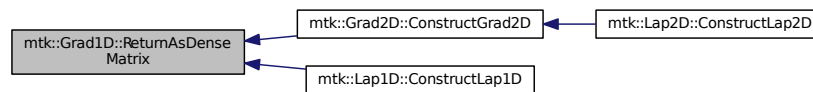
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 360 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

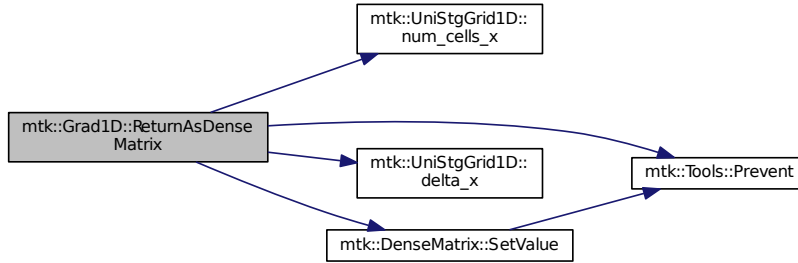
#### Returns

The operator as a dense matrix.

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

Definition at line 428 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



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

Returns

The operator as a dimensionless dense matrix.

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

Definition at line 492 of file [mtk\\_grad\\_1d.cc](#).

Here is the call graph for this function:



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

Returns

Collection of weights as computed by the CBSA.

Definition at line 340 of file [mtk\\_grad\\_1d.cc](#).

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

#### Returns

Success of the solution.

Definition at line 335 of file [mtk\\_grad\\_1d.cc](#).

### 16.8.4 Friends And Related Function Documentation

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

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

Definition at line 79 of file [mtk\\_grad\\_1d.cc](#).

### 16.8.5 Member Data Documentation

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

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

16.8.5.2 `int mtk::Grad1D::dim_null_` [*private*]

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

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

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

16.8.5.4 `int mtk::Grad1D::gradient_length_` [*private*]

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

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

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

16.8.5.6 `Real mtk::Grad1D::mimetic_threshold_` [*private*]

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



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

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

16.8.5.8 `int mtk::Grad1D::num_bndy_approx_` [private]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Definition at line 219 of file [mtk\\_grad\\_1d.h](#).

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

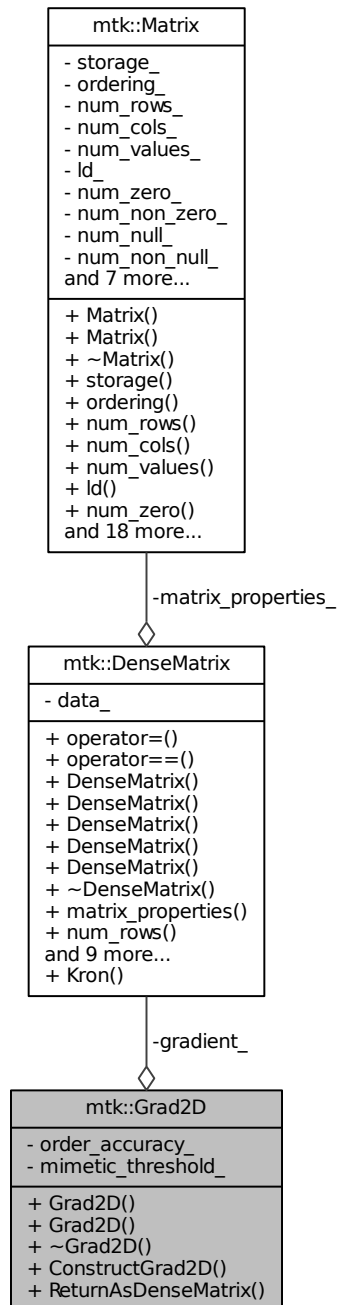
- [include/mtk\\_grad\\_1d.h](#)
- [src/mtk\\_grad\\_1d.cc](#)

## 16.9 mtk::Grad2D Class Reference

Implements a 2D mimetic gradient operator.

```
#include <mtk_grad_2d.h>
```

Collaboration diagram for mtk::Grad2D:



## Public Member Functions

- [Grad2D](#) ()

*Default constructor.*

- [Grad2D](#) (const [Grad2D](#) &grad)

*Copy constructor.*

- [~Grad2D](#) ()

*Destructor.*

- bool [ConstructGrad2D](#) (const [UniStgGrid2D](#) &grid, int order\_accuracy=[kDefaultOrderAccuracy](#), [Real](#) mimetic\_↔ threshold=[kDefaultMimeticThreshold](#))

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

- [DenseMatrix ReturnAsDenseMatrix](#) () const

*Return the operator as a dense matrix.*

## Private Attributes

- [DenseMatrix](#) gradient\_

*Actual operator.*

- int [order\\_accuracy\\_](#)

*Order of accuracy.*

- [Real](#) [mimetic\\_threshold\\_](#)

*Mimetic Threshold.*

## 16.9.1 Detailed Description

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

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

## 16.9.2 Constructor & Destructor Documentation

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

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

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

Parameters

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

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

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

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

### 16.9.3 Member Function Documentation

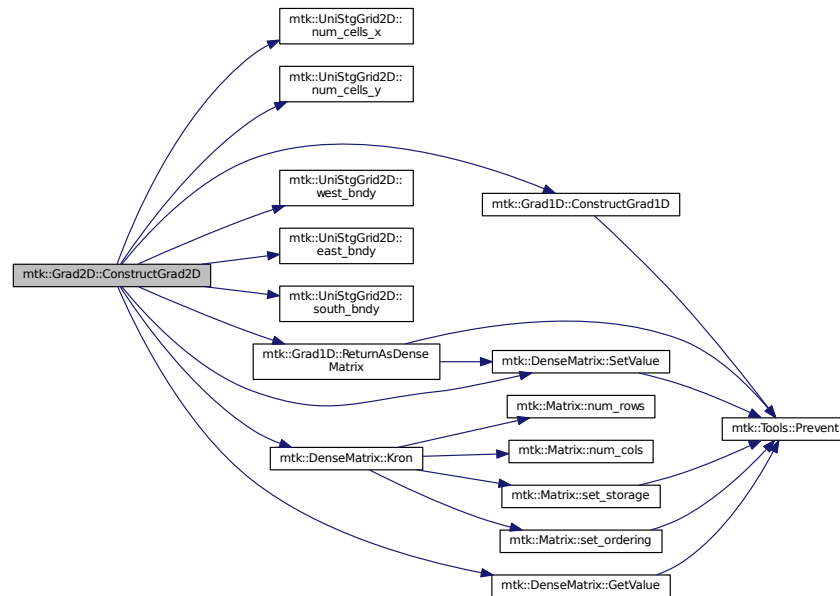
16.9.3.1 `bool mtk::Grad2D::ConstructGrad2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### Returns

Success of the construction.

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

Here is the call graph for this function:



Here is the caller graph for this function:



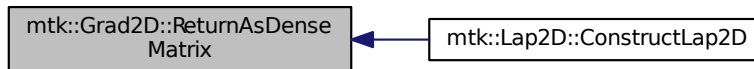
16.9.3.2 `mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix ( ) const`

**Returns**

The operator as a dense matrix.

Definition at line 143 of file [mtk\\_grad\\_2d.cc](#).

Here is the caller graph for this function:

**16.9.4 Member Data Documentation****16.9.4.1 DenseMatrix mtk::Grad2D::gradient\_ [private]**

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

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

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

**16.9.4.3 int mtk::Grad2D::order\_accuracy\_ [private]**

Definition at line 110 of file [mtk\\_grad\\_2d.h](#).

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

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

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

### 16.10.1 Detailed Description

This class implements a 1D interpolation operator.

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

### 16.10.2 Constructor & Destructor Documentation

#### 16.10.2.1 mtk::Interp1D::Interp1D ( )

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

#### 16.10.2.2 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](#).

#### 16.10.2.3 mtk::Interp1D::~~Interp1D ( )

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

### 16.10.3 Member Function Documentation

#### 16.10.3.1 mtk::Real \* mtk::Interp1D::coeffs\_interior ( ) const

Returns

Coefficients for the interior of the grid.

Definition at line 130 of file [mtk\\_interp\\_1d.cc](#).

#### 16.10.3.2 bool mtk::Interp1D::ConstructInterp1D ( int *order\_accuracy* = kDefaultOrderAccuracy, mtk::DirInterp *dir* = SCALAR\_TO\_VECTOR )

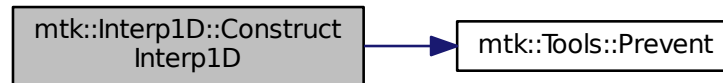
**Returns**

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:



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

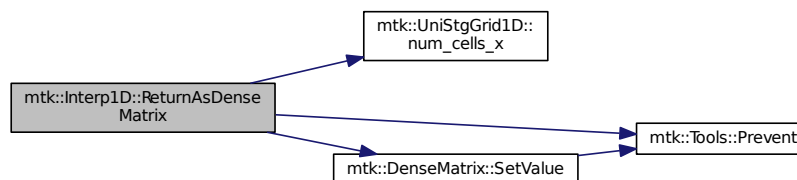
**Returns**

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 135 of file [mtk\\_interp\\_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::Interp1D & in ) [friend]`

1. Print approximating coefficients for the interior.

Definition at line 66 of file [mtk\\_interp\\_1d.cc](#).



### 16.10.5 Member Data Documentation

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

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

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

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

#### 16.10.5.3 `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:

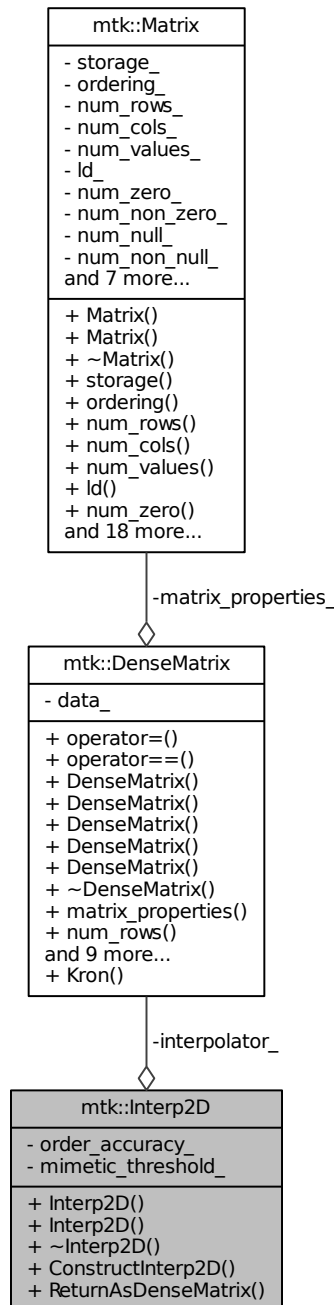
- [include/mtk\\_interp\\_1d.h](#)
- [src/mtk\\_interp\\_1d.cc](#)

## 16.11 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.*

## 16.11.1 Detailed Description

This class implements a 2D interpolation operator.

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

## 16.11.2 Constructor & Destructor Documentation

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

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

Parameters

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

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

## 16.11.3 Member Function Documentation

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

Returns

Success of the construction.

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

#### Returns

The operator as a dense matrix.

## 16.11.4 Member Data Documentation

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

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

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

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

### 16.11.4.3 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:

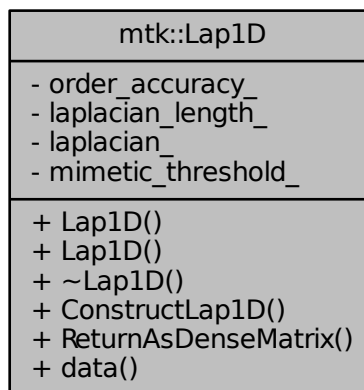
- [include/mtk\\_interp\\_2d.h](#)

## 16.12 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.*
- 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](#) [mimetic\\_threshold\\_](#)  
*< Mimetic threshold.*

## Friends

- std::ostream & [operator<<](#) (std::ostream &stream, [Lap1D](#) &in)  
*Output stream operator for printing.*

### 16.12.1 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](#).

### 16.12.2 Constructor & Destructor Documentation

#### 16.12.2.1 mtk::Lap1D::Lap1D ( )

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

#### 16.12.2.2 mtk::Lap1D::Lap1D ( const [Lap1D](#) &lap )

## Parameters

<code>in</code>	<code>lap</code>	Given Laplacian.
-----------------	------------------	------------------

16.12.2.3 `mtk::Lap1D::~~Lap1D ( )`

Definition at line 113 of file [mtk\\_lap\\_1d.cc](#).

## 16.12.3 Member Function Documentation

16.12.3.1 `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.

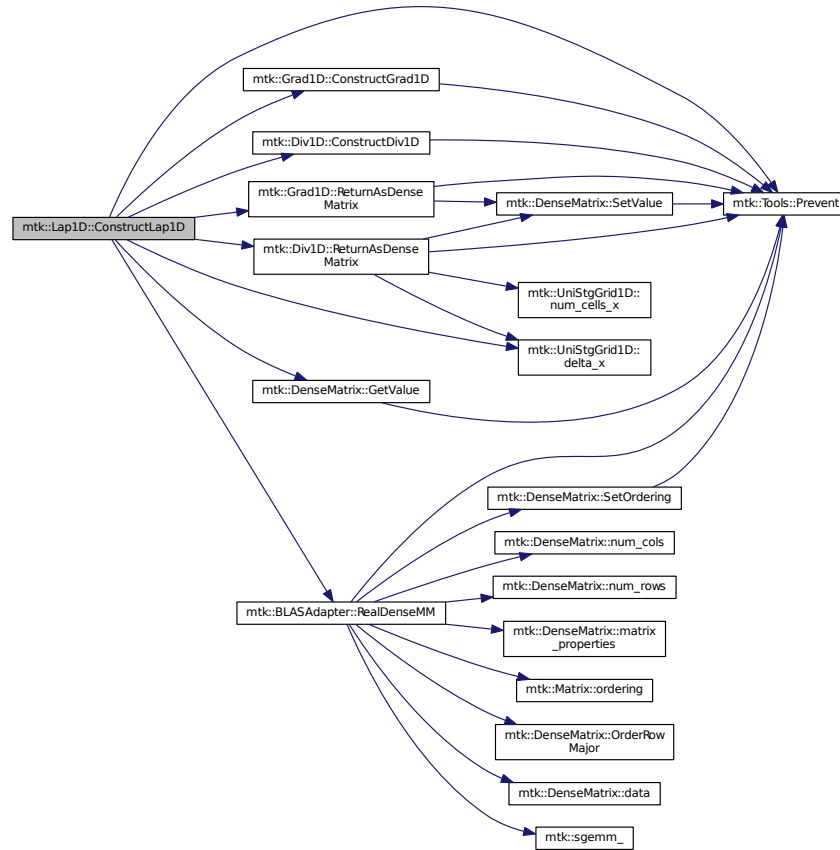
## Warning

We do not compute weights for this operator.

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 119 of file [mtk\\_lap\\_1d.cc](#).

Here is the call graph for this function:



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

#### Returns

The operator as a dense array.

Definition at line 333 of file [mtk\\_lap\\_1d.cc](#).

Here is the call graph for this function:



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

#### Returns

The operator as a dense matrix.

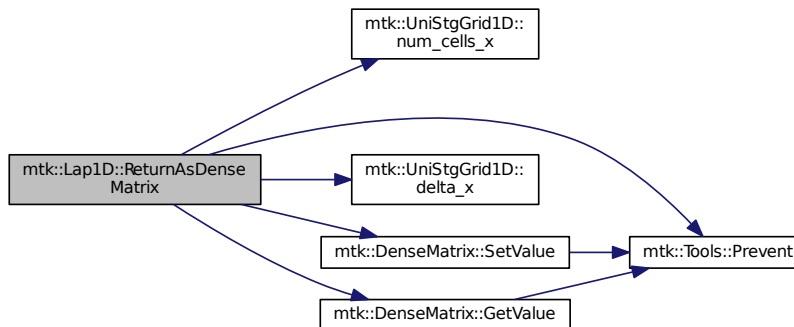
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

#### 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 265 of file [mtk\\_lap\\_1d.cc](#).

Here is the call graph for this function:



## 16.12.4 Friends And Related Function Documentation

### 16.12.4.1 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](#).

## 16.12.5 Member Data Documentation

### 16.12.5.1 Real\* mtk::Lap1D::laplacian\_ [private]

Definition at line 120 of file [mtk\\_lap\\_1d.h](#).



16.12.5.2 `int mtk::Lap1D::laplacian_length_ [private]`

Definition at line 118 of file [mtk\\_lap\\_1d.h](#).

16.12.5.3 `Real mtk::Lap1D::mimetic_threshold_ [private]`

Definition at line 122 of file [mtk\\_lap\\_1d.h](#).

16.12.5.4 `int mtk::Lap1D::order_accuracy_ [private]`

Definition at line 117 of file [mtk\\_lap\\_1d.h](#).

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

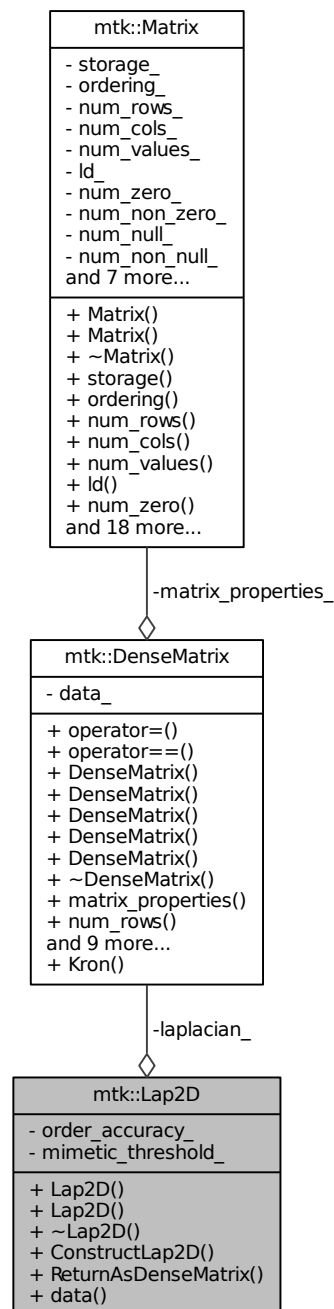
- [include/mtk\\_lap\\_1d.h](#)
- [src/mtk\\_lap\\_1d.cc](#)

## 16.13 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.*

### 16.13.1 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](#).

### 16.13.2 Constructor & Destructor Documentation

#### 16.13.2.1 mtk::Lap2D::Lap2D ( )

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

#### 16.13.2.2 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](#).

#### 16.13.2.3 mtk::Lap2D::~~Lap2D ( )

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

### 16.13.3 Member Function Documentation

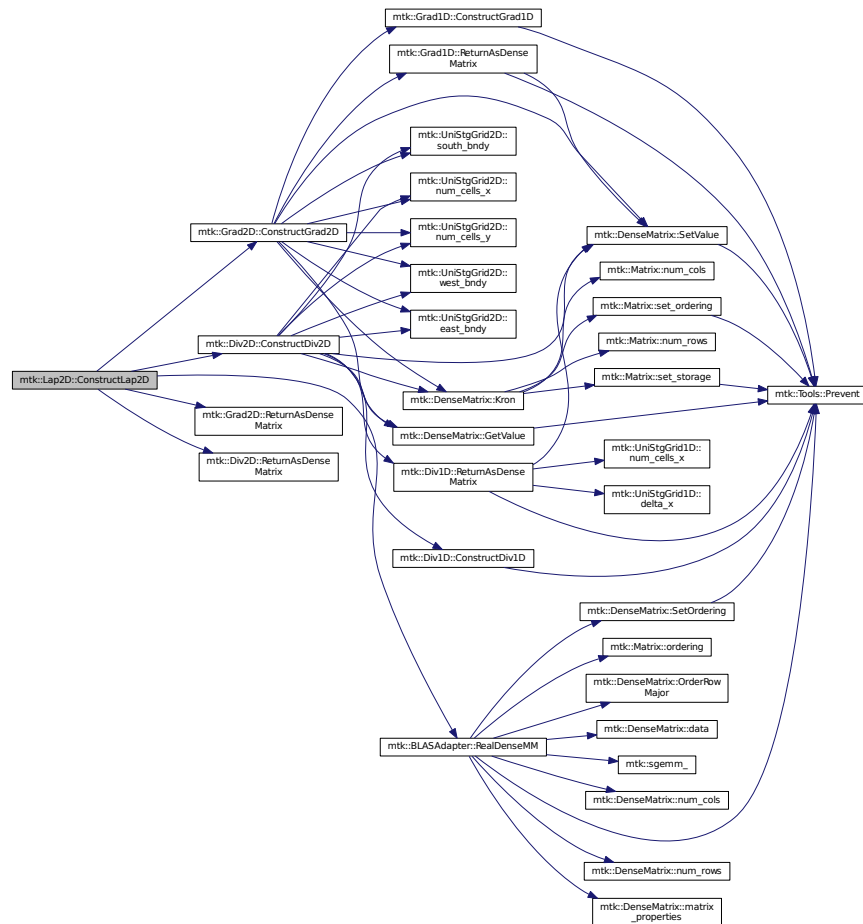
16.13.3.1 `bool mtk::Lap2D::ConstructLap2D ( const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold )`

#### Returns

Success of the construction.

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

Here is the call graph for this function:



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

#### Returns

The operator as a dense array.

Definition at line 111 of file [mtk\\_lap\\_2d.cc](#).

16.13.3.3 **mtk::DenseMatrix** mtk::Lap2D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 106 of file [mtk\\_lap\\_2d.cc](#).

## 16.13.4 Member Data Documentation

16.13.4.1 **DenseMatrix** mtk::Lap2D::laplacian\_ [private]

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

16.13.4.2 **Real** mtk::Lap2D::mimetic\_threshold\_ [private]

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

16.13.4.3 **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:

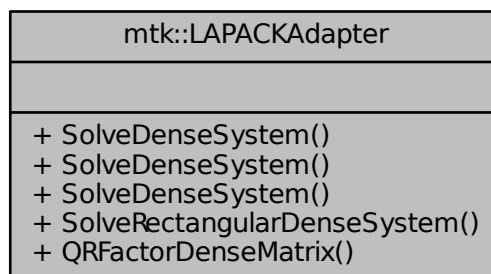
- [include/mtk\\_lap\\_2d.h](#)
- [src/mtk\\_lap\\_2d.cc](#)

## 16.14 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.*

### 16.14.1 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](#).

### 16.14.2 Member Function Documentation

#### 16.14.2.1 [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

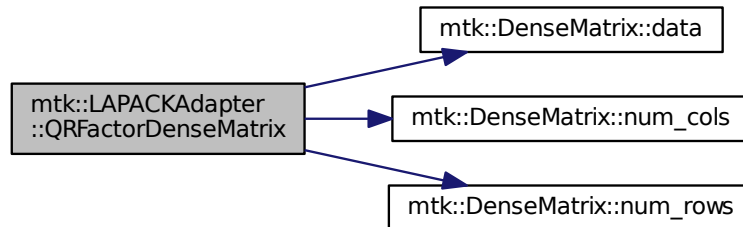
[Matrix](#) Q.

Exceptions

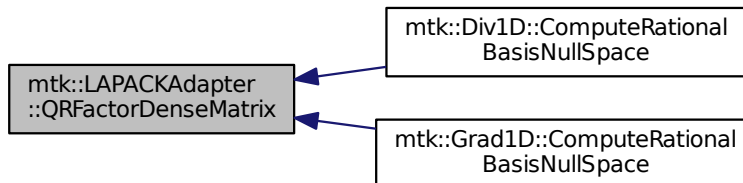
<i>std::bad_alloc</i>
-----------------------

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:



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

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

#### Parameters

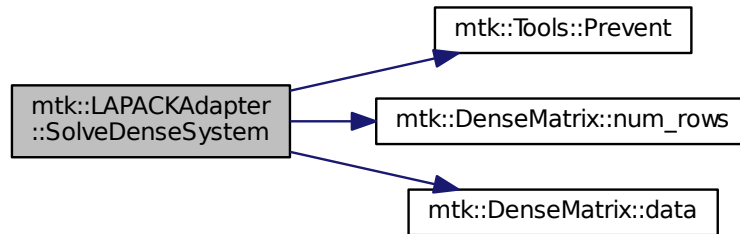
<code>in</code>	<code>matrix</code>	Input matrix.
<code>in</code>	<code>rhs</code>	Input right-hand sides vector.

#### Exceptions

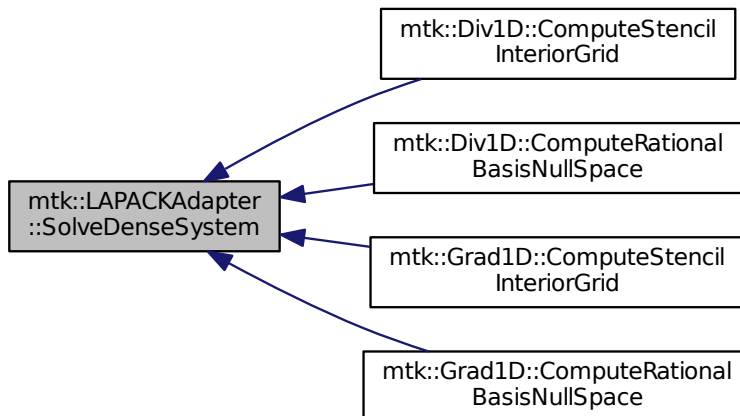
<code>std::bad_alloc</code>	
-----------------------------	--

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:



**16.14.2.3** `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.

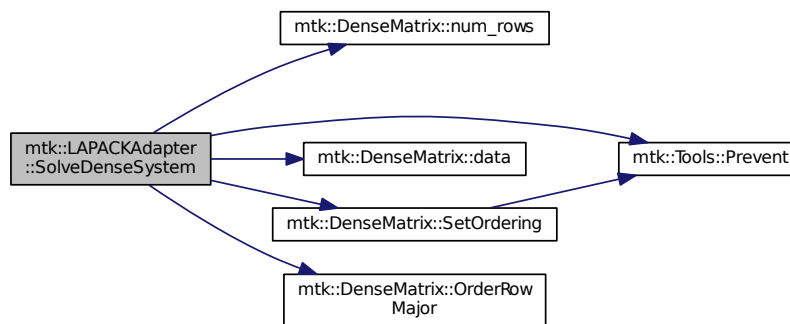


## Exceptions

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

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

Here is the call graph for this function:



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

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

## Parameters

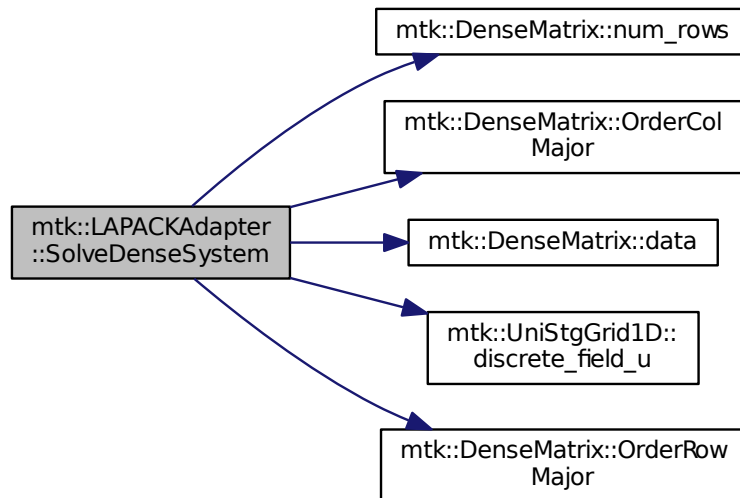
<code>in</code>	<code>matrix</code>	Input matrix.
<code>in</code>	<code>rr</code>	Input right-hand side from info on a grid.

## Exceptions

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

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

Here is the call graph for this function:



16.14.2.5 `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**

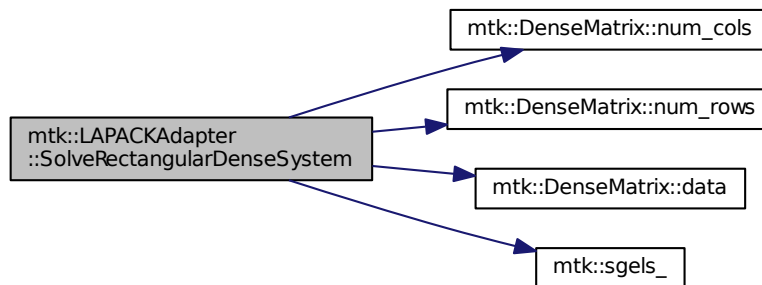
Success of the solution.

**Exceptions**

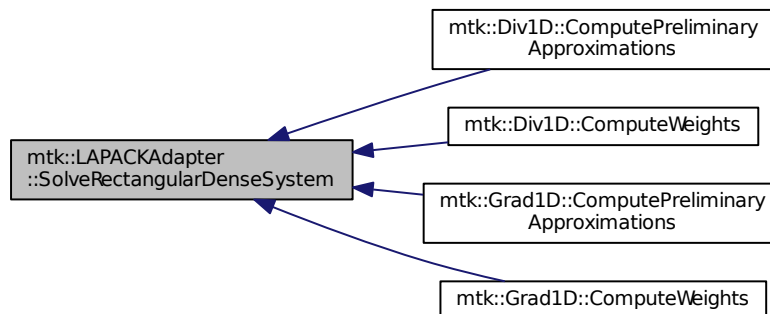
<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line 756 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](#)

## 16.15 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.*

### 16.15.1 Detailed Description

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

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

### 16.15.2 Constructor & Destructor Documentation

#### 16.15.2.1 `mtk::Matrix::Matrix ( )`

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

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

## Parameters

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

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

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

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

### 16.15.3 Member Function Documentation

16.15.3.1 `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.

16.15.3.2 `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](#).

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

Returns

Bandwidth of the matrix.

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

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

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

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



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

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

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

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

Returns

Number of lower diagonals.

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

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

Returns

Number of upper diagonals.

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

16.15.3.8 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](#).

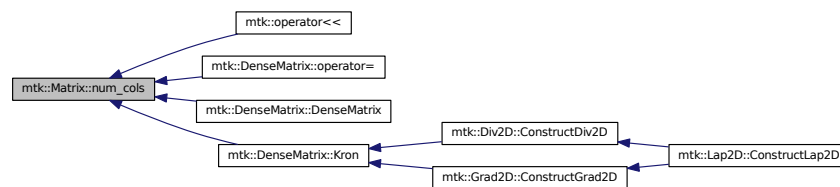
16.15.3.9 int mtk::Matrix::num\_cols ( ) const [noexcept]

Returns

Number of rows of the matrix.

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

Here is the caller graph for this function:



16.15.3.10 `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](#).

16.15.3.11 `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](#).

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

See also

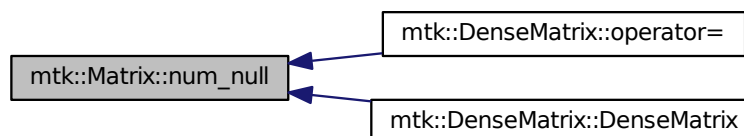
[http://www.csrc.sdsu.edu/research\\_reports/CSR2013-01.pdf](http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf)

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:



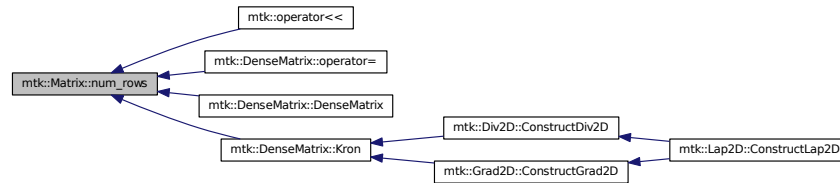
16.15.3.13 `int mtk::Matrix::num_rows ( ) const [noexcept]`

**Returns**

Number of rows of the matrix.

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

Here is the caller graph for this function:



#### 16.15.3.14 int mtk::Matrix::num\_values ( ) const [noexcept]

**Returns**

Number of values of the matrix.

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

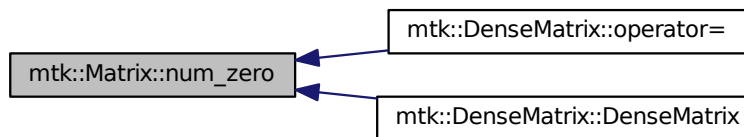
#### 16.15.3.15 int mtk::Matrix::num\_zero ( ) const [noexcept]

**Returns**

Number of zeros of the matrix.

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

Here is the caller graph for this function:



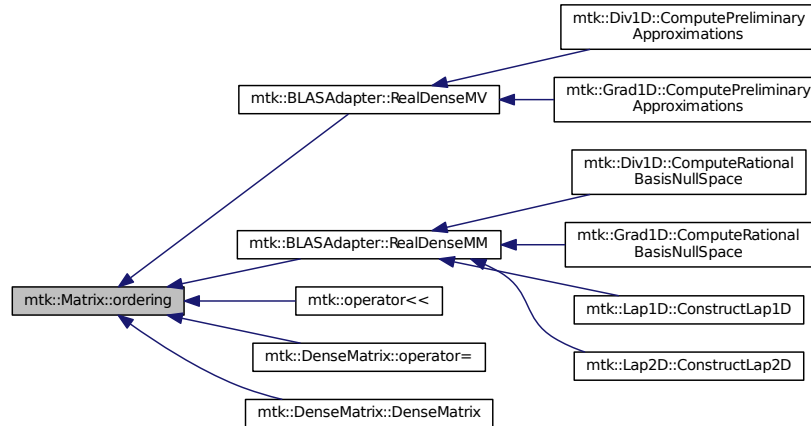
#### 16.15.3.16 mtk::MatrixOrdering mtk::Matrix::ordering ( ) const [noexcept]

**Returns**

Type of ordering of this matrix.

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

Here is the caller graph for this function:



16.15.3.17 **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](#).

16.15.3.18 **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](#).

16.15.3.19 **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:



**16.15.3.20** 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:



**16.15.3.21** `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:



**16.15.3.22** `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:



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

See also

[MatrixOrdering](#)

#### Parameters

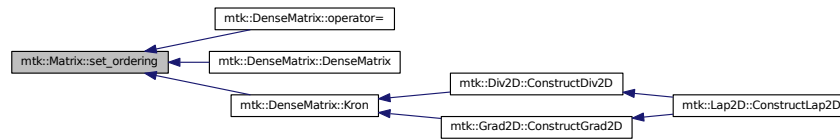
<code>in</code>	<code>oo</code>	Ordering of the matrix.
-----------------	-----------------	-------------------------

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:



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

See also

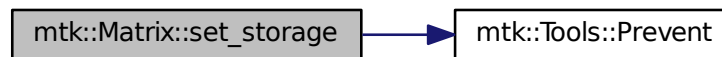
[MatrixStorage](#)

Parameters

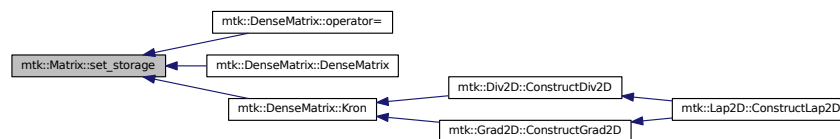
in	tt	Type of the matrix storage.
----	----	-----------------------------

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:



16.15.3.25 mtk::MatrixStorage mtk::Matrix::storage ( ) const [noexcept]

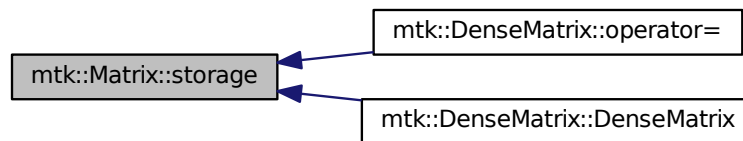


## Returns

Type of storage of this matrix.

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

Here is the caller graph for this function:



### 16.15.4 Member Data Documentation

#### 16.15.4.1 Real mtk::Matrix::abs\_density\_ [private]

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

#### 16.15.4.2 Real mtk::Matrix::abs\_sparsity\_ [private]

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

#### 16.15.4.3 int mtk::Matrix::bandwidth\_ [private]

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

#### 16.15.4.4 int mtk::Matrix::kl\_ [private]

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

#### 16.15.4.5 int mtk::Matrix::ku\_ [private]

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

#### 16.15.4.6 int mtk::Matrix::ld\_ [private]

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

#### 16.15.4.7 int mtk::Matrix::num\_cols\_ [private]

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

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

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

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

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

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

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

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

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

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

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

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

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

16.15.4.14 **MatrixOrdering** `mtk::Matrix::ordering_ [private]`

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

16.15.4.15 **Real** `mtk::Matrix::rel_density_ [private]`

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

16.15.4.16 **Real** `mtk::Matrix::rel_sparsity_ [private]`

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

16.15.4.17 **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:

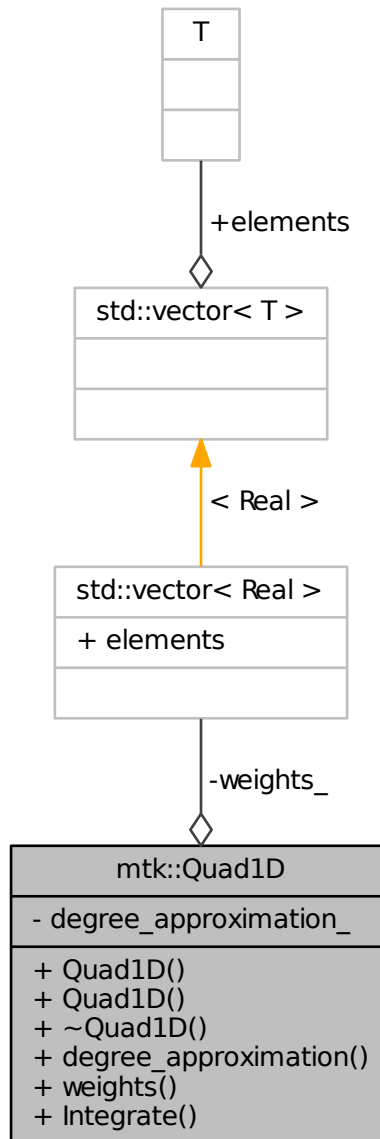
- [include/mtk\\_matrix.h](#)
- [src/mtk\\_matrix.cc](#)

## 16.16 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.*

### 16.16.1 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](#).

### 16.16.2 Constructor & Destructor Documentation

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

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

#### Parameters

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

16.16.2.3 `mtk::Quad1D::~~Quad1D ( )`

### 16.16.3 Member Function Documentation

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

#### Returns

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

16.16.3.2 `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.

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

#### Returns

Collection of weights.

### 16.16.4 Friends And Related Function Documentation

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

### 16.16.5 Member Data Documentation

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

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

16.16.5.2 `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:

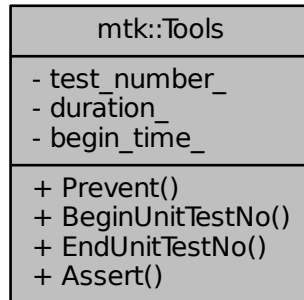
- [include/mtk\\_quad\\_1d.h](#)

## 16.17 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 114 of file [mtk\\_tools.cc](#).

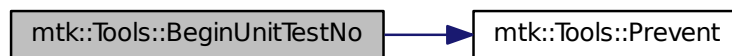
16.17.2.2 void mtk::Tools::BeginUnitTestNo ( const int & *nn* ) [static], [noexcept]

## Parameters

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

Definition at line 91 of file [mtk\\_tools.cc](#).

Here is the call graph for this function:



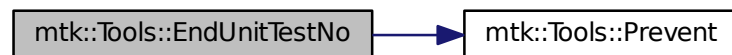
16.17.2.3 void mtk::Tools::EndUnitTestNo ( const int & *nn* ) [static], [noexcept]

## Parameters

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

Definition at line 105 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**

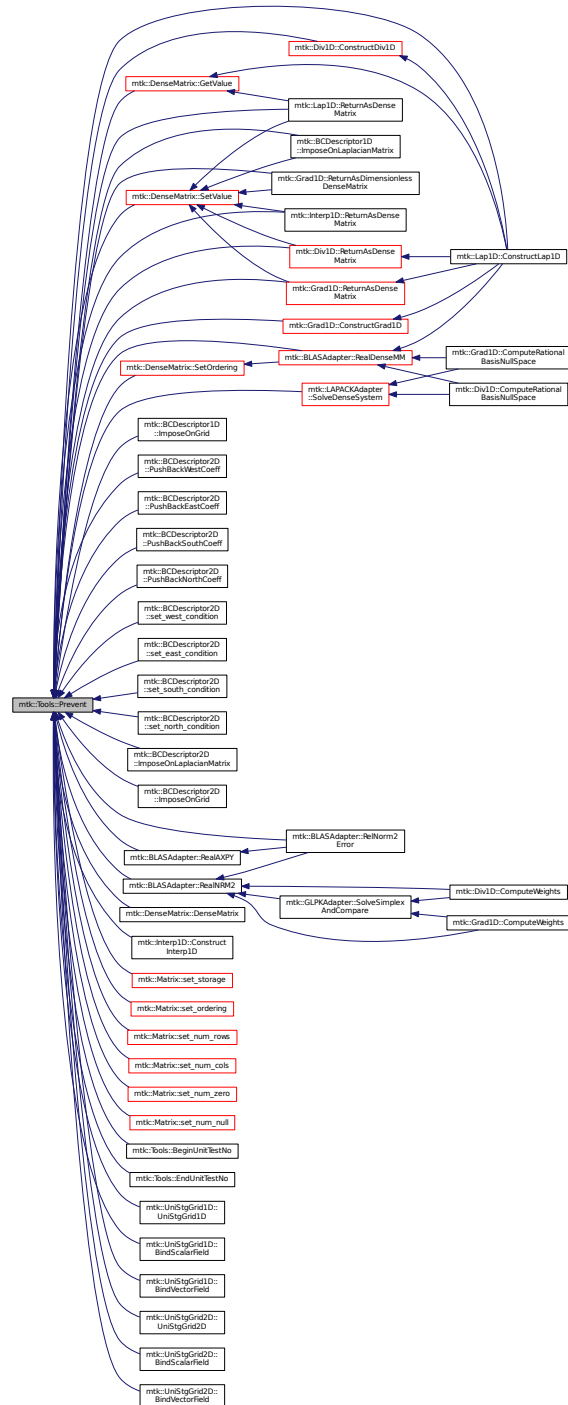
in	<i>complement</i>	Complement of desired pre-condition.
in	<i>fname</i>	Name of the file being checked.
in	<i>lineno</i>	Number of the line where the check is executed.
in	<i>fxname</i>	Name of the module containing the check.

**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:

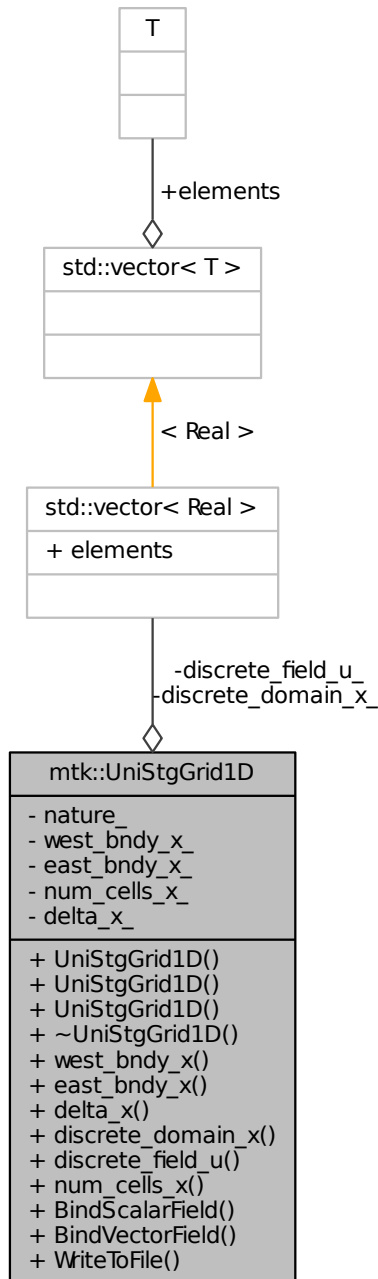
- [include/mtk\\_tools.h](#)
- [src/mtk\\_tools.cc](#)

## 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\_u ()

*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)([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\_u\_

*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(\*) (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:



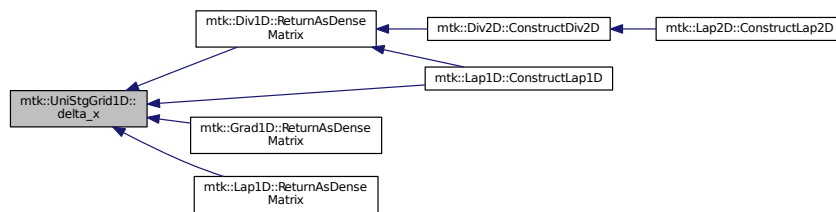
## 16.18.3.3 mtk::Real mtk::UniStgGrid1D::delta\_x ( ) const

## 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\_u ( )

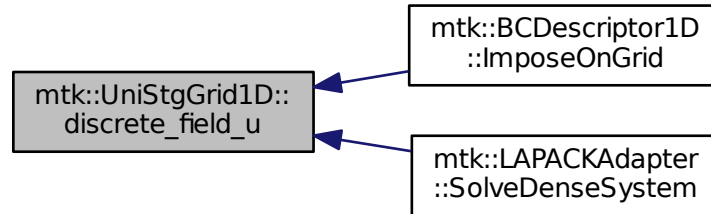
**Returns**

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](#).

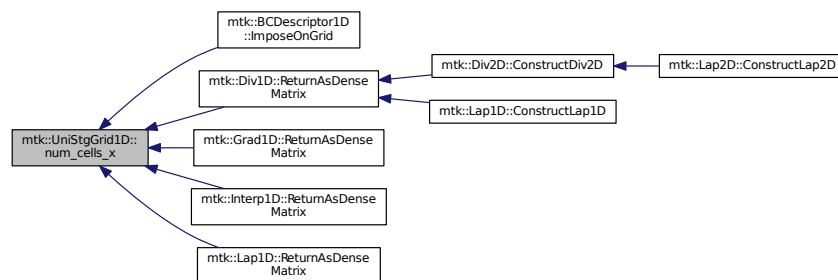
### 16.18.3.7 int mtk::UniStgGrid1D::num\_cells\_x ( ) const

**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_u_` [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:

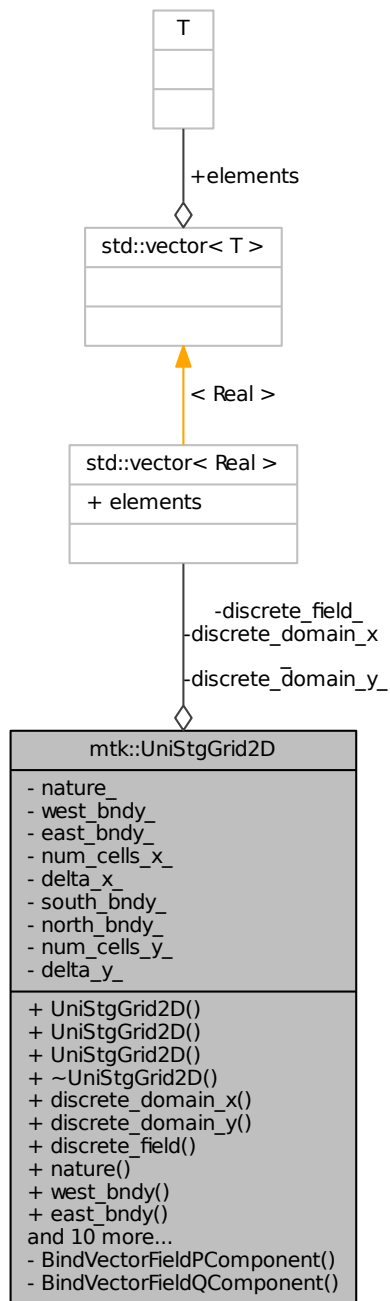
- [include/mtk\\_uni\\_stg\\_grid\\_1d.h](#)
- [src/mtk\\_uni\\_stg\\_grid\\_1d.cc](#)

## 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.*

- const `Real` \* `discrete_field` () const

*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)(`Real` xx, `Real` yy))

*Binds a given scalar field to the grid.*

- void BindVectorField (`Real`(\*VectorFieldPComponent)(`Real` xx, `Real` yy), `Real`(\*VectorFieldQComponent)(`Real` xx, `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)([Real](#) xx, [Real](#) yy))  
*Binds a given component of a vector field to the grid.*
- void [BindVectorFieldQComponent](#) ([Real](#)(\*VectorFieldQComponent)([Real](#) xx, [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

<code>in</code>	<code>grid</code>	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

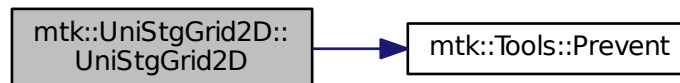
<code>in</code>	<code>west_bndy_x</code>	Coordinate for the west boundary.
<code>in</code>	<code>east_bndy_x</code>	Coordinate for the east boundary.
<code>in</code>	<code>num_cells_x</code>	Number of cells of the required grid.
<code>in</code>	<code>south_bndy_y</code>	Coordinate for the west boundary.
<code>in</code>	<code>north_bndy_y</code>	Coordinate for the east boundary.
<code>in</code>	<code>num_cells_y</code>	Number of cells of the required grid.
<code>in</code>	<code>nature</code>	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(\*) (Real xx, Real yy) *ScalarField* )

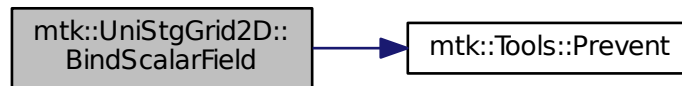
##### Parameters

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(\*) (Real xx, Real yy) *VectorFieldPComponent*, Real(\*) (Real xx, Real yy) *VectorFieldQComponent* )

We assume the field to be of the form:

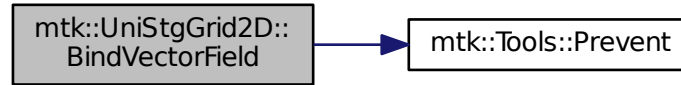
$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

##### 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 413 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(*) (Real xx, 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 320 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

16.19.3.4 `void mtk::UniStgGrid2D::BindVectorFieldQComponent ( Real(*) (Real xx, 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 385 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:



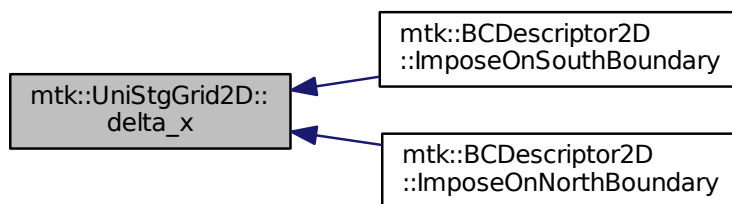
16.19.3.6 `mtk::Real mtk::UniStgGrid2D::delta_x ( ) const`

#### Returns

Computed  $\Delta x$ .

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

Here is the caller graph for this function:



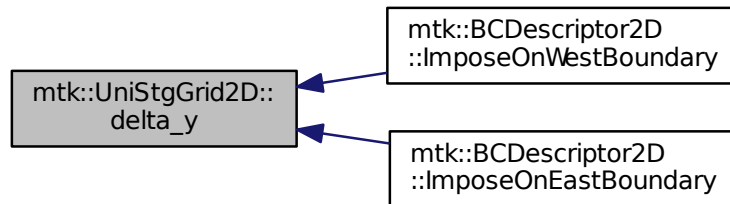
16.19.3.7 `mtk::Real mtk::UniStgGrid2D::delta_y ( ) const`

## 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`

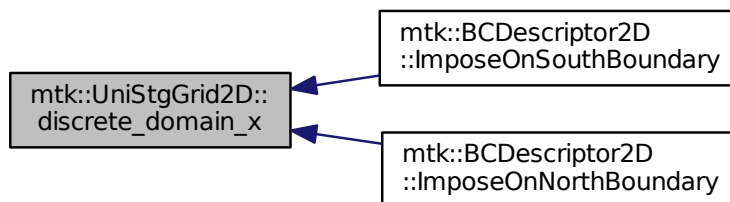
## Returns

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`

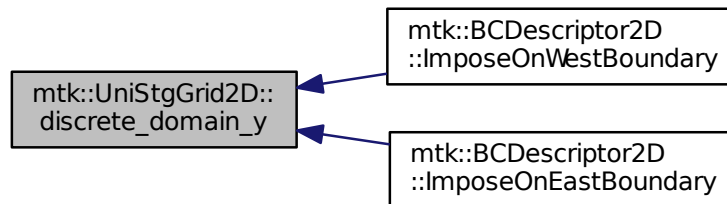
**Returns**

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 `const mtk::Real * mtk::UniStgGrid2D::discrete_field ( ) const`

**Returns**

Pointer to the field data.

Definition at line 265 of file [mtk\\_uni\\_stg\\_grid\\_2d.cc](#).

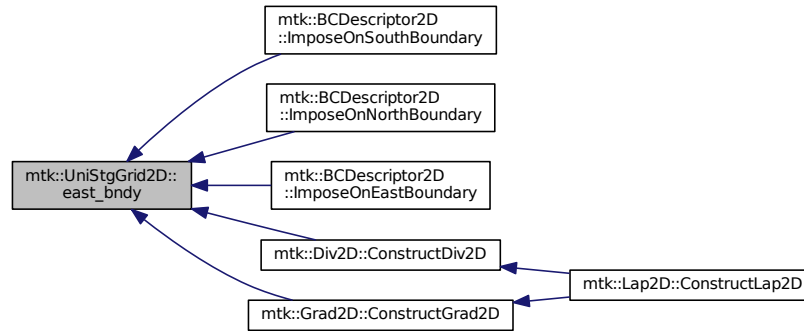
16.19.3.11 `mtk::Real mtk::UniStgGrid2D::east_bndy ( ) const`

**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:



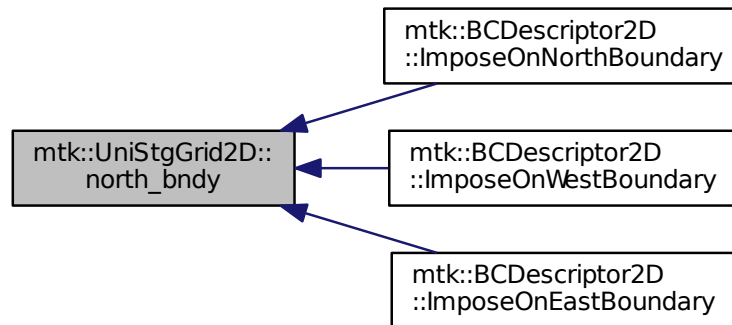
### 16.19.3.13 `mtk::Real mtk::UniStgGrid2D::north_bndy ( ) const`

**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:



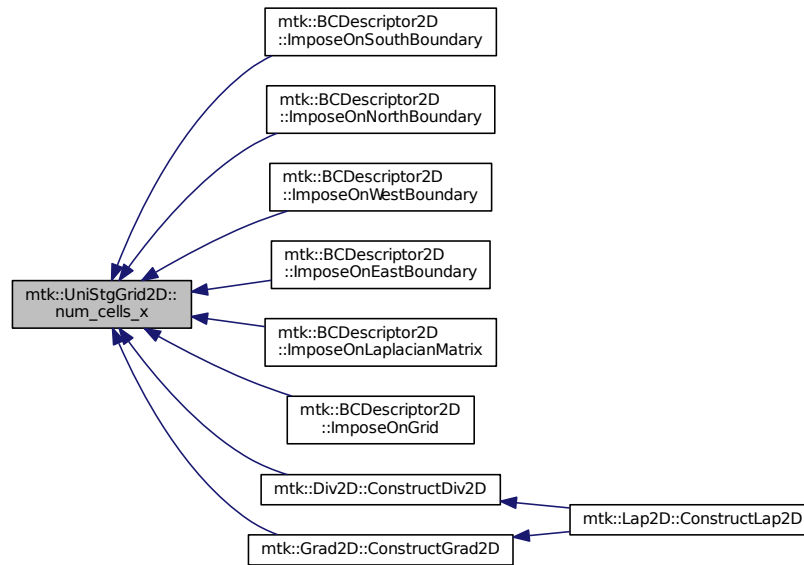
16.19.3.14 `int mtk::UniStgGrid2D::num_cells_x ( ) const`

**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:



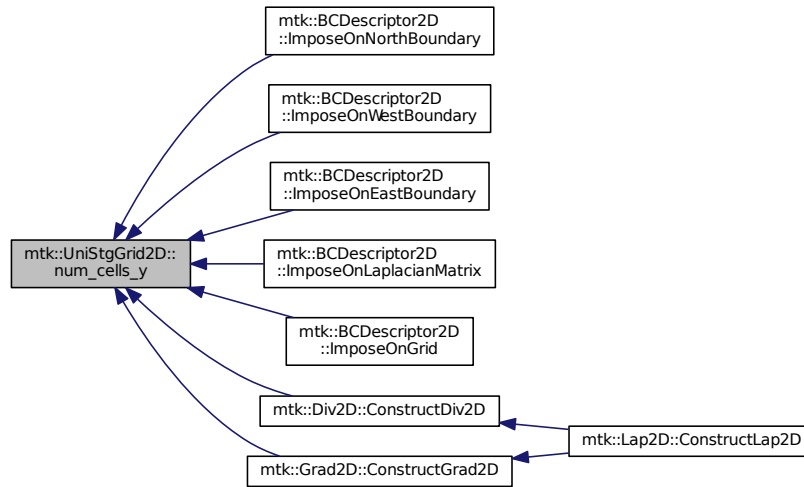
16.19.3.15 `int mtk::UniStgGrid2D::num_cells_y ( ) const`

#### 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:



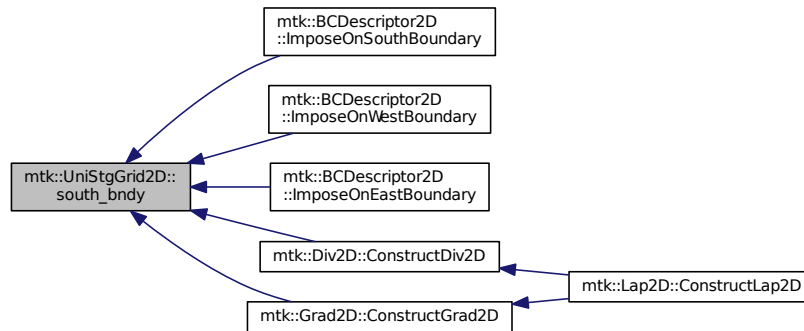
#### 16.19.3.16 mtk::Real mtk::UniStgGrid2D::south\_bndy ( ) const

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:



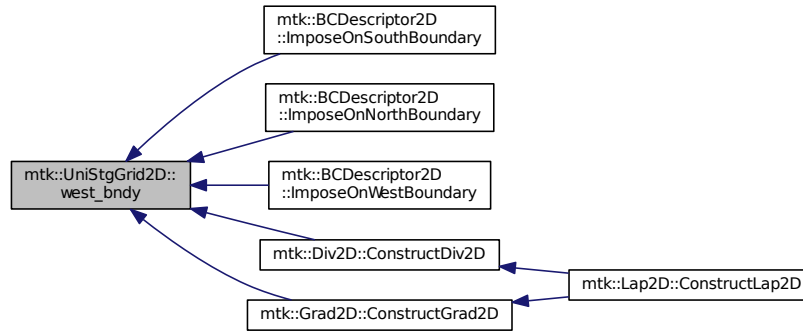
#### 16.19.3.17 mtk::Real mtk::UniStgGrid2D::west\_bndy ( ) const

**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 425 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 296 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

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

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

Definition at line 287 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

Definition at line 288 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

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

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

Definition at line 294 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

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

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

Definition at line 299 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

Definition at line 295 of file [mtk\\_uni\\_stg\\_grid\\_2d.h](#).

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

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

16.19.5.11 **Real** mtk::UniStgGrid2D::south\_bndy\_ [private]

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

16.19.5.12 **Real** mtk::UniStgGrid2D::west\_bndy\_ [private]

Definition at line 293 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

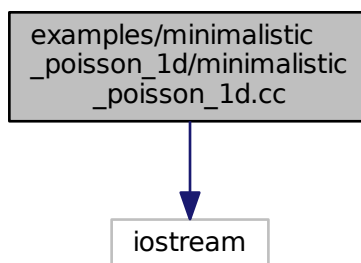
# File Documentation

### 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 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 [minimalistic\\_poisson\\_1d.cc](#).

## 17.1.2 Function Documentation

### 17.1.2.1 int main ( )

Definition at line 167 of file [minimalistic\\_poisson\\_1d.cc](#).

## 17.2 minimalistic\_poisson\_1d.cc

```

00001
00042 /*
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00045
00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
00048
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
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00061
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```

```

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00074 parties intellectual property rights.
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00078 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00079 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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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 #include <vector>
00094
00095 #include "mtk.h"
00096
00097 mtk::Real Source(mtk::Real xx) {
00098     mtk::Real lambda = -1.0;
00099     return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00100 }
00101
00102 mtk::Real KnownSolution(mtk::Real xx) {
00103     mtk::Real lambda = -1.0;
00104     return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00105 }
00106
00107 int main () {
00108
00109     mtk::Real west_bndy_x = 0.0;
00110     mtk::Real east_bndy_x = 1.0;
00111     mtk::Real relative_norm_2_error{};
00112     int num_cells_x = 5;
00113     mtk::Grad1D grad;
00114     mtk::Lap1D lap;
00115     std::vector<mtk::Real> west_coeffs;
00116     std::vector<mtk::Real> east_coeffs;
00117     mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00118     mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00119     mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00120
00121     if (!lap.ConstructLap1D()) {
00122         std::cerr << "Mimetic lap could not be built." << std::endl;
00123         return EXIT_FAILURE;
00124     }
00125     mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00126     if (!grad.ConstructGrad1D()) {
00127         std::cerr << "Mimetic grad could not be built." << std::endl;
00128         return EXIT_FAILURE;
00129     }
00130     mtk::DenseMatrix gradm(grad.ReturnAsDenseMatrix(comp_sol));
00131
00132     source.BindScalarField(Source);
00133
00134     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00135         west_coeffs.push_back(-(exp(-1.0) - 1.0)/-1.0)*gradm.GetValue(0, ii));
00136     }
00137     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00138         east_coeffs.push_back(
00139             (exp(-1.0) - 1.0)/-1.0)*gradm.GetValue(gradm.num_rows() - 1,
00140             gradm.num_cols() - 1 - ii);
00141     }
00142     west_coeffs[0] += -exp(-1.0);
00143     east_coeffs[0] += -exp(-1.0);
00144     mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(lapm,
00145         west_coeffs, east_coeffs);

```

```

00145   mtk::BCDescriptor1D::ImposeOnGrid(source, -1.0, 0.0);
00146
00147   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00148   if (info != 0) {
00149       std::cerr << "Something wrong solving system! info = " << info << std::endl;
00150       return EXIT_FAILURE;
00151   }
00152
00153   source.WriteToFile("minimalistic_poisson_1d_comp_sol.dat", "x", "~u(x)");
00154   known_sol.BindScalarField(KnownSolution);
00155   relative_norm_2_error =
00156       mtk::BLASAdapter::RelNorm2Error(source.discrete_field_u(),
00157                                       known_sol.discrete_field_u(),
00158                                       known_sol.num_cells_x());
00159   std::cout << "relative_norm_2_error = ";
00160   std::cout << relative_norm_2_error << std::endl;
00161 }
00162
00163 #else
00164 #include <iostream>
00165 using std::cout;
00166 using std::endl;
00167 int main () {
00168     cout << "This code HAS to be compiled with support for C++11." << endl;
00169     cout << "Exiting..." << endl;
00170     return EXIT_SUCCESS;
00171 }
00172 #endif

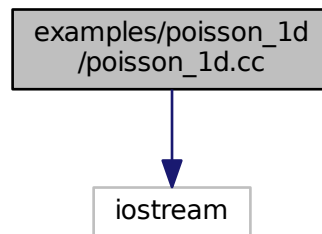
```

## 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 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\\_1d.cc](#).

### 17.3.2 Function Documentation

#### 17.3.2.1 int main ( )

Definition at line 261 of file [poisson\\_1d.cc](#).

## 17.4 poisson\_1d.cc

```
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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
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```

```

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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 mtk::Real Source(mtk::Real xx) {
00099
00100     mtk::Real lambda = -1.0;
00101
00102     return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00103 }
00104
00105 mtk::Real KnownSolution(mtk::Real xx) {
00106
00107     mtk::Real lambda = -1.0;
00108
00109     return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00110 }
00111
00112 int main () {
00113
00114     std::cout << "Example: Poisson Equation on a 1D Uniform Staggered Grid ";
00115     std::cout << "with Robin BCs." << std::endl;
00116
00117     mtk::Real lambda = -1.0;
00118     mtk::Real alpha = -exp(lambda);
00119     mtk::Real beta = (exp(lambda) - 1.0)/lambda;
00120     mtk::Real omega = -1.0;
00121     mtk::Real epsilon = 0.0;
00122
00123     mtk::Real west_bndy_x = 0.0;
00124     mtk::Real east_bndy_x = 1.0;
00125     int num_cells_x = 5;
00126
00127     mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00128
00129     int order_of_accuracy{2}; // Desired order of accuracy for approximation.
00130
00131     mtk::Grad1D grad; // Mimetic gradient operator.
00132
00133     mtk::Lapl1D lap; // Mimetic Laplacian operator.
00134
00135     if (!lap.ConstructLapl1D(order_of_accuracy)) {
00136         std::cerr << "Mimetic lap could not be built." << std::endl;
00137         return EXIT_FAILURE;
00138     }
00139
00140     mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));

```



```

00147
00148     std::cout << "Mimetic Laplacian operator: " << std::endl;
00149     std::cout << lapm << std::endl;
00150
00151     if (!grad.ConstructGrad1D(order_of_accuracy)) {
00152         std::cerr << "Mimetic grad could not be built." << std::endl;
00153         return EXIT_FAILURE;
00154     }
00155
00156     mtk::DenseMatrix gradm(grad.ReturnAsDenseMatrix(comp_sol));
00157
00158     std::cout << "Mimetic gradient operator: " << std::endl;
00159     std::cout << gradm << std::endl;
00160
00161
00162
00163     mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00164
00165     source.BindScalarField(Source);
00166
00167     std::cout << source << std::endl;
00168
00169
00170     // Since we need to approximate the first derivative times beta, we must use
00171     // the approximation of the gradient at the boundary. We could extract them
00172     // from the gradient operator as packed in the grad object. BUT, since we have
00173     // generated at matrix containing this operator, we can extract these from the
00174     // matrix.
00175
00176     // Array containing the coefficients for the west boundary condition.
00177     std::vector<mtk::Real> west_coeffs;
00178
00179     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00180         west_coeffs.push_back(-beta*gradm.GetValue(0, ii));
00181     }
00182
00183     // Array containing the coefficients for the east boundary condition.
00184     std::vector<mtk::Real> east_coeffs;
00185
00186     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00187         east_coeffs.push_back(beta*gradm.GetValue(gradm.num_rows() - 1,
00188                                                    gradm.num_cols() - 1 - ii));
00189     }
00190
00191     // To impose the Dirichlet condition, we simple add its coefficient to the
00192     // first entry of the west, and the last entry of the east array.
00193
00194     west_coeffs[0] += alpha;
00195
00196     east_coeffs[0] += alpha;
00197
00198     // Now that we have the coefficients that should be in the operator, we create
00199     // a boundary condition descriptor object, which will encapsulate the
00200     // complexity of assigning them in the matrix, to complete the construction of
00201     // the mimetic operator.
00202
00203     mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(lapm,
00204     west_coeffs, east_coeffs);
00205
00206     std::cout << "Mimetic Laplacian with Robin conditions:" << std::endl;
00207     std::cout << lapm << std::endl;
00208
00209     mtk::BCDescriptor1D::ImposeOnGrid(source, omega, epsilon);
00210
00211     std::cout << "Source term with imposed BCs:" << std::endl;
00212     std::cout << source << std::endl;
00213
00214     source.WriteToFile("poisson_1d_source.dat", "x", "s(x)");
00215
00216
00217     int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00218
00219     if (!info) {
00220         std::cout << "System solved! Problem solved!" << std::endl;
00221         std::cout << std::endl;
00222     }
00223     else {
00224         std::cerr << "Something wrong solving system! info = " << info << std::endl;
00225         std::cerr << "Exiting..." << std::endl;
00226         return EXIT_FAILURE;
00227     }
00228
00229

```

```

00230     std::cout << "Computed solution:" << std::endl;
00231     std::cout << source << std::endl;
00232
00233     source.WriteToFile("poisson_1d_comp_sol.dat", "x", "~u(x)");
00234
00236
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     known_sol.WriteToFile("poisson_1d_known_sol.dat", "x", "u(x)");
00245
00246     mtk::Real relative_norm_2_error{}; // Relative norm 2 of the error.
00247
00248     relative_norm_2_error =
00249         mtk::BLASAdapter::RelNorm2Error(source.discrete_field_u(),
00250                                         known_sol.discrete_field_u(),
00251                                         known_sol.num_cells_x());
00252
00253     std::cout << "relative_norm_2_error = ";
00254     std::cout << relative_norm_2_error << std::endl;
00255 }
00256
00257 #else
00258 #include <iostream>
00259 using std::cout;
00260 using std::endl;
00261 int main () {
00262     cout << "This code HAS to be compiled with support for C++11." << endl;
00263     cout << "Exiting..." << endl;
00264     return EXIT_SUCCESS;
00265 }
00266 #endif

```

## 17.5 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_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_bc_descriptor_2d.h"

```



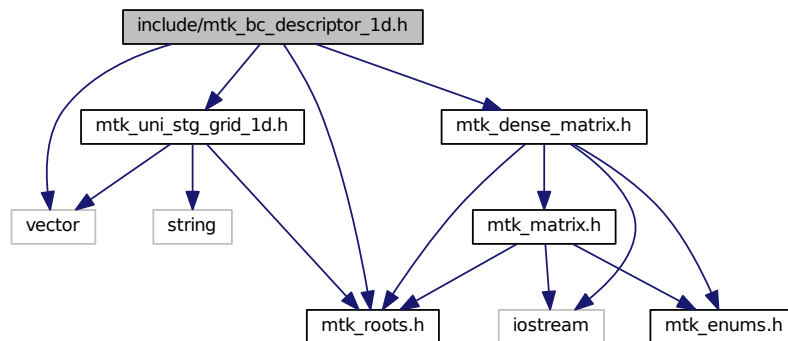
```
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00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
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_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_bc_descriptor_2d.h"
00458
00459 #endif // End of: MTK_INCLUDE_MTK_H_
```

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

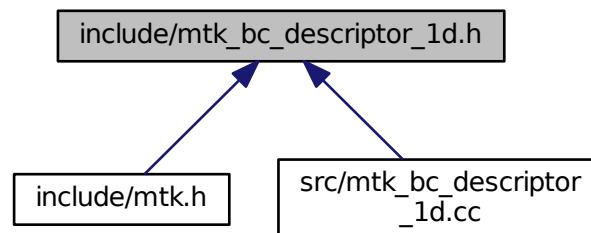
Enforces boundary conditions in either the operator or the grid.

```
#include <vector>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
```

Include dependency graph for mtk\_bc\_descriptor\_1d.h:



This graph shows which files directly or indirectly include this file:



## Classes

- class [mtk::BCDescriptor1D](#)  
*Enforces boundary conditions in either the operator or the grid.*

## Namespaces

- [mtk](#)  
*Mimetic Methods Toolkit namespace.*

### 17.7.1 Detailed Description

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

**Author**

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

Definition in file [mtk\\_bc\\_descriptor\\_1d.h](#).

**17.8 mtk\_bc\_descriptor\_1d.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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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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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 <vector>
00058
00059 #include "mtk_roots.h"
00060 #include "mtk_dense_matrix.h"
00061 #include "mtk_uni_stg_grid_1d.h"
00062
00063 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
00064 #define MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
00065
00066 namespace mtk {
00067
00068 class BCDescriptor1D {
00069 public:
00070     static void ImposeOnLaplacianMatrix(DenseMatrix &matrix,
00071                                         const std::vector<Real> &west,
00072                                         const std::vector<Real> &east);
00073
00074     static void ImposeOnGrid(UniStgGrid1D &grid,
00075                             const Real &epsilon,
00076                             const Real &omega);
00077 };
00078
00079
00080
00081
00082
00083
00084
00085
00086
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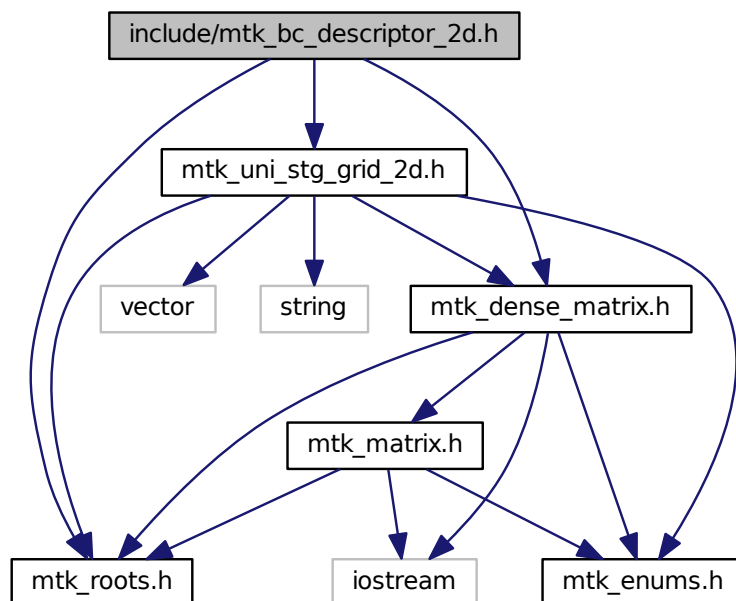
```

```
00102 }  
00103 #endif // End of: MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
```

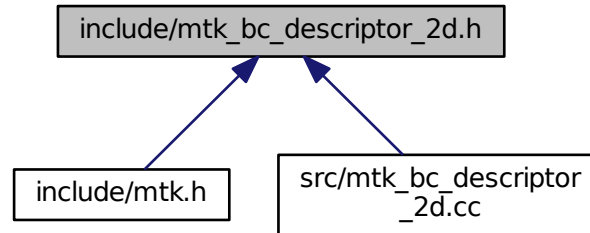
## 17.9 include/mtk\_bc\_descriptor\_2d.h File Reference

Imposes boundary conditions in either the operator or the grid.

```
#include "mtk_roots.h"  
#include "mtk_dense_matrix.h"  
#include "mtk_uni_stg_grid_2d.h"  
Include dependency graph for mtk_bc_descriptor_2d.h:
```



This graph shows which files directly or indirectly include this file:



## Classes

- class [mtk::BCDescriptor2D](#)  
*Enforces boundary conditions in either the operator or the grid.*

## Namespaces

- [mtk](#)  
*Mimetic Methods Toolkit namespace.*

## Typedefs

- typedef `Real(* mtk::CoefficientFunction2D )(const Real &, const Real &)`  
*A function of a BC coefficient evaluated on a 2D domain.*

### 17.9.1 Detailed Description

This class presents an interface for the user to specify boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let  $f$  be any scalar or vector field defined over a domain  $\Omega$ . We can specify any linear combination of  $f$  and its  $n$  derivatives to fulfill a condition, which we define as a **boundary condition**:

$$\forall \mathbf{x} \in \partial\Omega : \sum_{i=0}^n c_i(\mathbf{x}) < \hat{\mathbf{n}}, \frac{\partial^i f}{\partial x^i}(\mathbf{x}) > = \beta(\mathbf{x}).$$

This class receives information about the highest-order of differentiation,  $n$ , all possible coefficient functions,  $c_i(\mathbf{x})$  for any subset of the boundary (south, north, west and east), and each condition for any subset of the boundary, and takes care of assigning them to both, the differentiation matrices and the grids.



## Author

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

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

## 17.10 mtk\_bc\_descriptor\_2d.h

```

00001
00030 /*
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00032 University. All rights reserved.
00033
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00035 are permitted provided that the following conditions are met:
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00038 and a copy of the modified files should be reported once modifications are
00039 completed, unless these modifications are made through the project's GitHub
00040 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00041 should be developed and included in any deliverable.
00042
00043 2. Redistributions of source code must be done through direct
00044 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00071 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00072 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00073 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00074 */
00075
00076 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00077 #define MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00078
00079 #include "mtk_roots.h"
00080 #include "mtk_dense_matrix.h"
00081 #include "mtk_uni_stg_grid_2d.h"
00082
00083 namespace mtk{
00084
00092 typedef Real (*CoefficientFunction2D)(const Real &, const Real &);
00093
00123 class BCDescriptor2D {
00124 public:
00126   BCDescriptor2D();
00127
00133   BCDescriptor2D(const BCDescriptor2D &desc);
00134
00136   ~BCDescriptor2D() noexcept;
00137
00143   int highest_order_diff_west() const noexcept;
00144

```

```

00150 int highest_order_diff_east() const noexcept;
00151
00157 int highest_order_diff_south() const noexcept;
00158
00164 int highest_order_diff_north() const noexcept;
00165
00171 void PushBackWestCoeff(CoefficientFunction2D cw);
00172
00178 void PushBackEastCoeff(CoefficientFunction2D ce);
00179
00185 void PushBackSouthCoeff(CoefficientFunction2D cs);
00186
00192 void PushBackNorthCoeff(CoefficientFunction2D cn);
00193
00199 void set_west_condition(Real (*west_condition)(Real xx, Real yy)) noexcept;
00200
00206 void set_east_condition(Real (*east_condition)(Real xx, Real yy)) noexcept;
00207
00213 void set_south_condition(Real (*south_condition)(Real xx, Real yy)) noexcept;
00214
00220 void set_north_condition(Real (*north_condition)(Real xx, Real yy)) noexcept;
00221
00229 void ImposeOnLaplacianMatrix(const UniStgGrid2D &grid,
00230                             DenseMatrix &matrix,
00231                             const int &order_accuracy = 2) const;
00232
00238 void ImposeOnGrid(UniStgGrid2D &grid) const;
00239
00240 private:
00248 void ImposeOnSouthBoundary(const mtk::UniStgGrid2D &grid,
00249                             mtk::DenseMatrix &matrix,
00250                             const int &order_accuracy) const;
00251
00259 void ImposeOnNorthBoundary(const mtk::UniStgGrid2D &grid,
00260                             mtk::DenseMatrix &matrix,
00261                             const int &order_accuracy) const;
00262
00270 void ImposeOnWestBoundary(const mtk::UniStgGrid2D &grid,
00271                             mtk::DenseMatrix &matrix,
00272                             const int &order_accuracy) const;
00273
00281 void ImposeOnEastBoundary(const mtk::UniStgGrid2D &grid,
00282                             mtk::DenseMatrix &matrix,
00283                             const int &order_accuracy) const;
00284
00285 mutable bool generate_space_;
00286
00287 int highest_order_diff_west_;
00288 int highest_order_diff_east_;
00289 int highest_order_diff_south_;
00290 int highest_order_diff_north_;
00291
00292 std::vector<CoefficientFunction2D> west_coefficients_;
00293 std::vector<CoefficientFunction2D> east_coefficients_;
00294 std::vector<CoefficientFunction2D> south_coefficients_;
00295 std::vector<CoefficientFunction2D> north_coefficients_;
00296
00297 Real (*west_condition_)(Real xx, Real yy);
00298 Real (*east_condition_)(Real xx, Real yy);
00299 Real (*south_condition_)(Real xx, Real yy);
00300 Real (*north_condition_)(Real xx, Real yy);
00301 };
00302 }
00303 #endif // End of: MTK_INCLUDE_BC_DESCRIPTOR_2D_H_

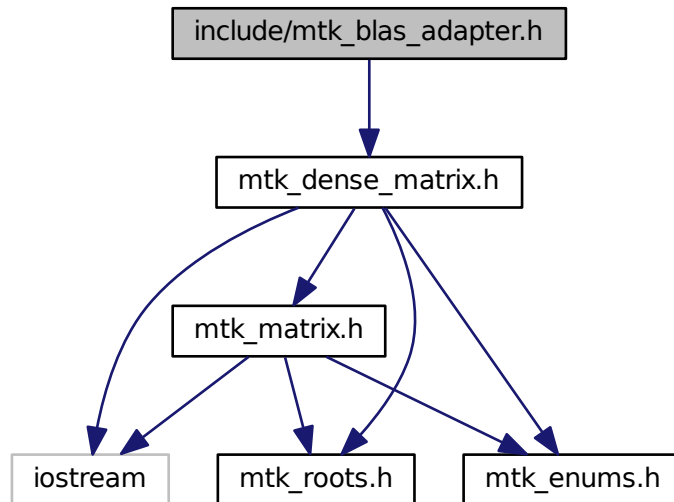
```

## 17.11 include/mtk\_blas\_adapter.h File Reference

Adapter class for the BLAS API.

```
#include "mtk_dense_matrix.h"
```

Include dependency graph for mtk\_blas\_adapter.h:



This graph shows which files directly or indirectly include this file:



## Classes

- class `mtk::BLASAdapter`  
*Adapter class for the BLAS API.*

## Namespaces

- `mtk`  
*Mimetic Methods Toolkit namespace.*

### 17.11.1 Detailed Description

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

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

The BLAS can be installed from links given in the See Also section of this page.

#### See also

<http://www.netlib.org/blas/>  
<https://software.intel.com/en-us/non-commercial-software-development>

#### Author

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

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

## 17.12 mtk\_blas\_adapter.h

```

00001
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00025 Copyright (C) 2015, Computational Science Research Center, San Diego State
00026 University. All rights reserved.
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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
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.
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00045 prior written permission from the the copyright holders, and due credit should
00046 be given to the copyright holders.
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00063 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00071 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00072
00073 #include "mtk_dense_matrix.h"

```

```

00074
00075 namespace mtk {
00076
00096 class BLASAdapter {
00097 public:
00106     static Real RealNRM2(Real *in, int &in_length);
00107
00124     static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00125
00140     static Real RelNorm2Error(Real *computed, Real *known, int length);
00141
00159     static void RealDenseMV(Real &alpha,
00160                             DenseMatrix &aa,
00161                             Real *xx,
00162                             Real &beta,
00163                             Real *yy);
00164
00179     static DenseMatrix RealDenseMM(DenseMatrix &aa,
00180                                    DenseMatrix &bb);
00181 };
00182 #endif // End of: MTK_INCLUDE_BLAS_ADAPTER_H_

```

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

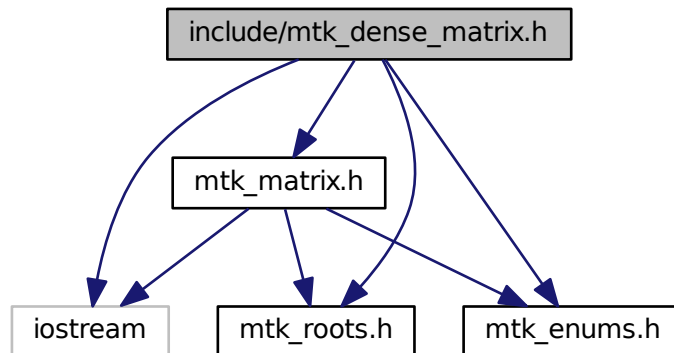
Defines a common dense matrix, using a 1D array.

```

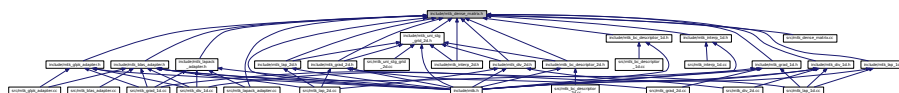
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_matrix.h"

```

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.*

### 17.13.1 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](#).

## 17.14 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
00038
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00040 this list of conditions and the following disclaimer in the documentation and/or
00041 other materials provided with the distribution.
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```

```

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00064 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00065 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
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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
00270     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_

```

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

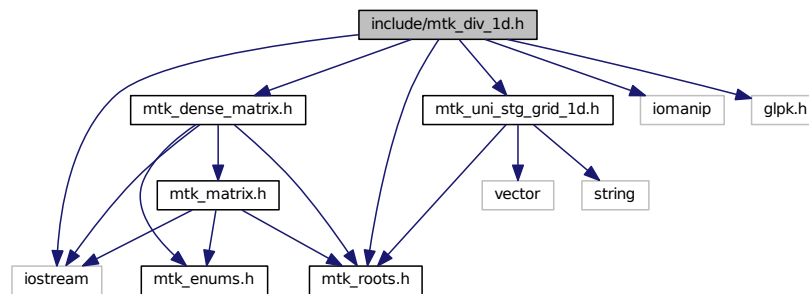
Includes the definition of the class Div1D.

```

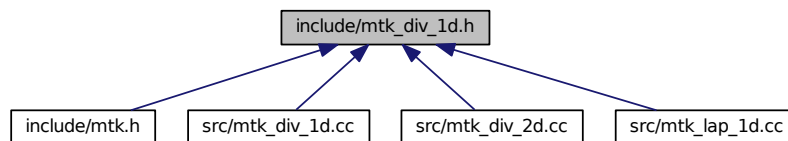
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.15.1 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](#).

## 17.16 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
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>

```

```

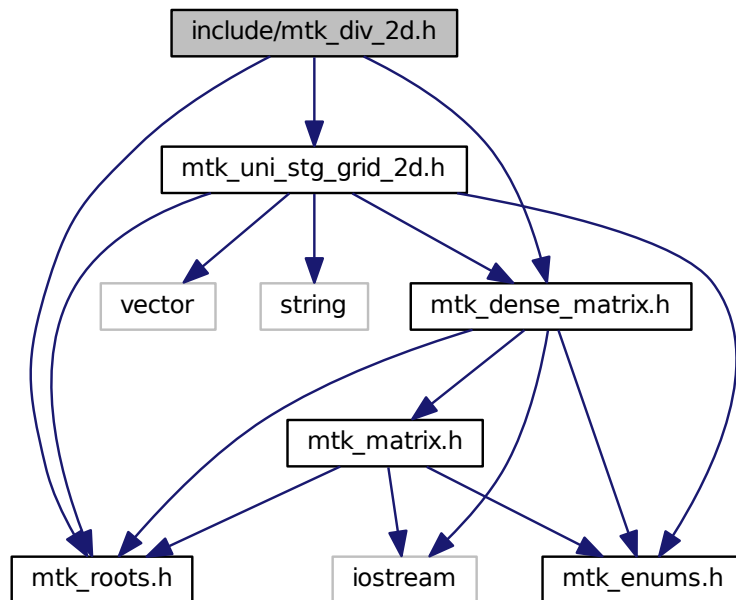
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Div1D {
00082 public:
00084     friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00085
00087     Div1D();
00088
00094     Div1D(const Div1D &div);
00095
00097     ~Div1D();
00098
00104     bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00105                        Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112     int num_bndy_coeffs() const;
00113
00119     Real *coeffs_interior() const;
00120
00126     Real *weights_crs(void) const;
00127
00133     Real *weights_cbs(void) const;
00134
00140     DenseMatrix mim_bndy() const;
00141
00147     DenseMatrix ReturnAsDenseMatrix(const
00148     UniStgGrid1D &grid) const;
00149 private:
00155     bool ComputeStencilInteriorGrid(void);
00156
00163     bool ComputeRationalBasisNullSpace(void);
00164
00170     bool ComputePreliminaryApproximations(void);
00171
00177     bool ComputeWeights(void);
00178
00184     bool ComputeStencilBoundaryGrid(void);
00185
00191     bool AssembleOperator(void);
00192
00193     int order_accuracy_;
00194     int dim_null_;
00195     int num_bndy_coeffs_;
00196     int divergence_length_;
00197     int minrow_;
00198     int row_;
00199
00200     DenseMatrix rat_basis_null_space_;
00201
00202     Real *coeffs_interior_;
00203     Real *prem_apps_;
00204     Real *weights_crs_;
00205     Real *weights_cbs_;
00206     Real *mim_bndy_;
00207     Real *divergence_;
00208
00209     Real mimetic_threshold_;
00210 };
00211 }
00212 #endif // End of: MTK_INCLUDE_DIV_1D_H_

```

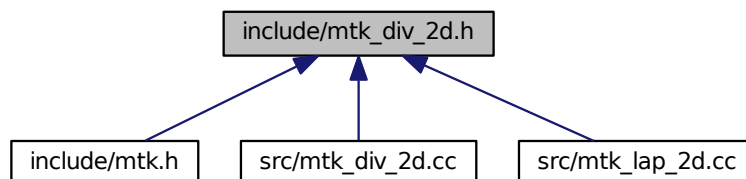
## 17.17 include/mtk\_div\_2d.h File Reference

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.*

### 17.17.1 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](#).

### 17.18 mtk\_div\_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:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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00028 this list of conditions and the following disclaimer in the documentation and/or
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00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_2D_H_
00058 #define MTK_INCLUDE_MTK_DIV_2D_H_
00059
00060 #include "mtk_roots.h"

```

```

00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Div2D {
00077 public:
00078     Div2D();
00080
00086     Div2D(const Div2D &div);
00087
00089     ~Div2D();
00090
00096     bool ConstructDiv2D(const UniStgGrid2D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105     DenseMatrix ReturnAsDenseMatrix() const;
00106
00107 private:
00108     DenseMatrix divergence_;
00109
00110     int order_accuracy_;
00111
00112     Real mimetic_threshold_;
00113 };
00114 }
00115 #endif // End of: MTK_INCLUDE_MTK_DIV_2D_H_

```

## 17.19 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.*

### 17.19.1 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](#).

### 17.20 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.
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00025 2. Redistributions of source code must be done through direct
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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_

```

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

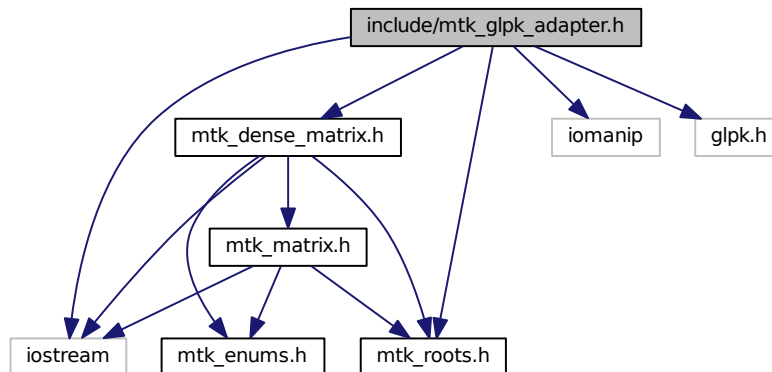
Adapter class for the GLPK API.

```

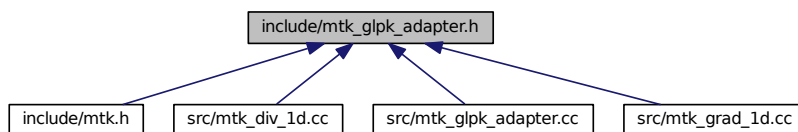
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"

```

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.*

### 17.21.1 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`.

## 17.22 mtk\_glpk\_adapter.h

```

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00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```



```

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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00066 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00067
00068 #include <iostream>
00069 #include <iomanip>
00070
00071 #include "glpk.h"
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075
00076 namespace mtk {
00077
00101 class GLPKAdapter {
00102 public:
00123     static mtk::Real SolveSimplexAndCompare(
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_

```

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

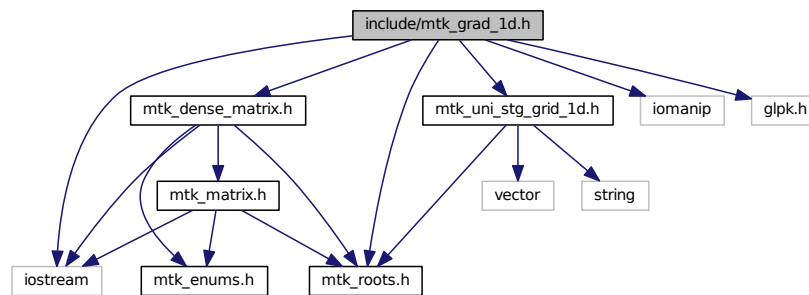
Includes the definition of the class Grad1D.

```

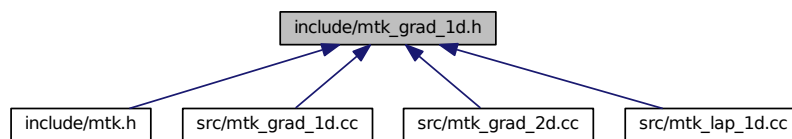
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.23.1 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](#).

## 17.24 mtk\_grad\_1d.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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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
00099
00100
00101
00102
00103
00104
00105
00106
00107
00108
00109
00110
00111
00112
00113
00114
00115
00116
00117
00118
00119
00120

```

```

00126     Real *weights_crs(void) const;
00127
00133     Real *weights_cbs(void) const;
00134
00140     DenseMatrix mim_bndy() const;
00141
00147     DenseMatrix ReturnAsDenseMatrix(Real west,
Real east, int num_cells_x) const;
00148
00154     DenseMatrix ReturnAsDenseMatrix(const
UniStgGrid1D &grid) const;
00155
00161     DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
const;
00162
00163 private:
00169     bool ComputeStencilInteriorGrid(void);
00170
00177     bool ComputeRationalBasisNullSpace(void);
00178
00184     bool ComputePreliminaryApproximations(void);
00185
00191     bool ComputeWeights(void);
00192
00198     bool ComputeStencilBoundaryGrid(void);
00199
00205     bool AssembleOperator(void);
00206
00207     int order_accuracy_;
00208     int dim_null_;
00209     int num_bndy_approxs_;
00210     int num_bndy_coeffs_;
00211     int gradient_length_;
00212     int minrow_;
00213     int row_;
00214
00215     DenseMatrix rat_basis_null_space_;
00216
00217     Real *coeffs_interior_;
00218     Real *prem_apps_;
00219     Real *weights_crs_;
00220     Real *weights_cbs_;
00221     Real *mim_bndy_;
00222     Real *gradient_;
00223
00224     Real mimetic_threshold_;
00225 };
00226 }
00227 #endif // End of: MTK_INCLUDE_GRAD_1D_H_

```

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

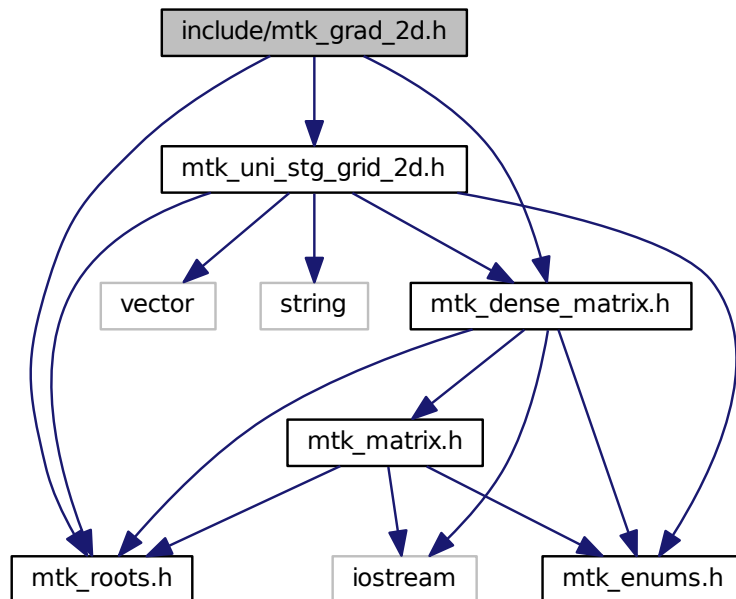
Includes the definition of the class Grad2D.

```

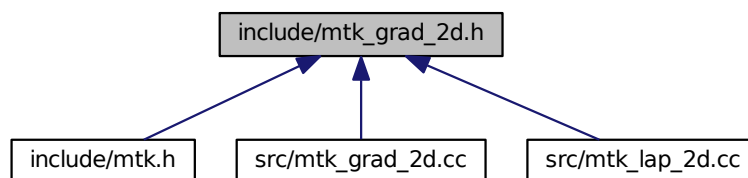
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"

```

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.*

### 17.25.1 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](#).

## 17.26 mtk\_grad\_2d.h

```

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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
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00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_2D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{

```

```

00065
00076 class Grad2D {
00077 public:
00079     Grad2D();
00080
00086     Grad2D(const Grad2D &grad);
00087
00089     ~Grad2D();
00090
00096     bool ConstructGrad2D(const UniStgGrid2D &grid,
00097                         int order_accuracy = kDefaultOrderAccuracy,
00098                         Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105     DenseMatrix ReturnAsDenseMatrix() const;
00106
00107 private:
00108     DenseMatrix gradient_;
00109
00110     int order_accuracy_;
00111
00112     Real mimetic_threshold_;
00113 };
00114 }
00115 #endif // End of: MTK_INCLUDE_MTK_GRAD_2D_H_

```

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

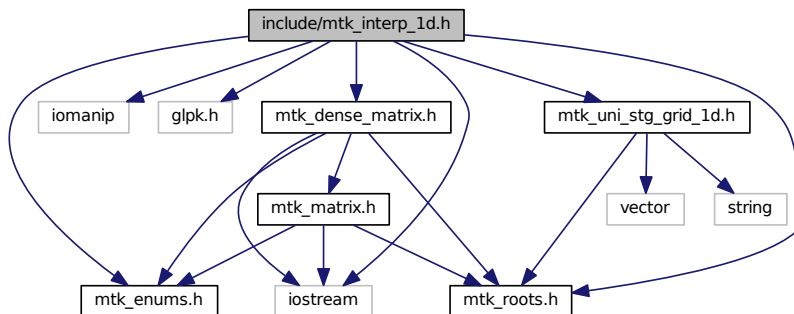
Includes the definition of the class Interp1D.

```

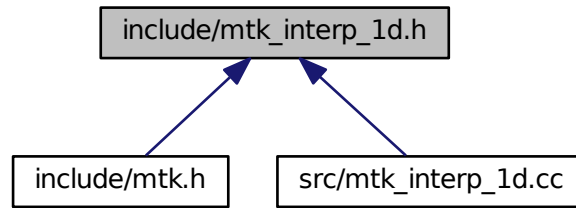
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.27.1 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`.

## 17.28 mtk\_interp\_1d.h

```

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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024

```



```

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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_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_

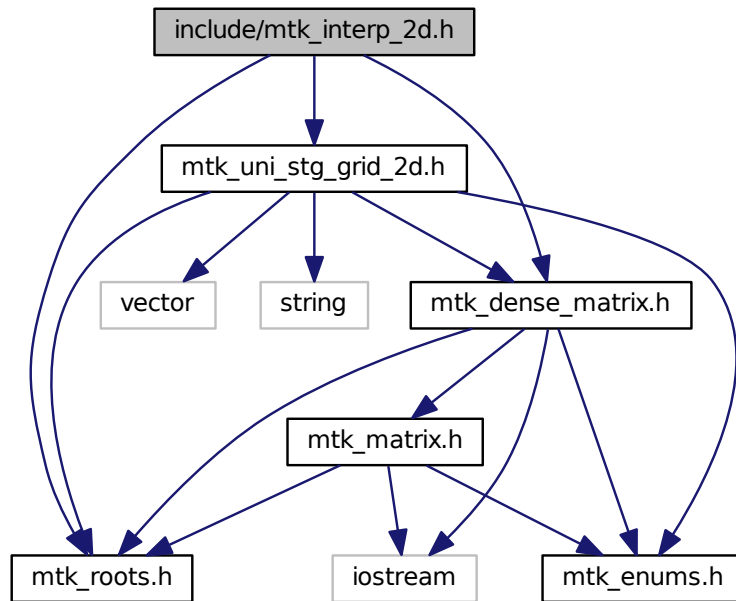
```

## 17.29 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.*

#### 17.29.1 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](#).

## 17.30 mtk\_interp\_2d.h

```

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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
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00025 2. Redistributions of source code must be done through direct
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00056 */
00057
00058 #ifndef MTK_INCLUDE_MTK_INTERP_2D_H_
00059 #define MTK_INCLUDE_MTK_INTERP_2D_H_
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_dense_matrix.h"
00063 #include "mtk_uni_stg_grid_2d.h"
00064
00065 namespace mtk{
00066
00076 class Interp2D {
00077 public:
00079   Interp2D();
00080
00086   Interp2D(const Interp2D &interp);
00087
00089   ~Interp2D();
00090
00096   DenseMatrix ConstructInterp2D(const UniStgGrid2D &grid,
00097                                int order_accuracy = kDefaultOrderAccuracy,

```

```

00098                                     Real mimetic_threshold =
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_

```

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

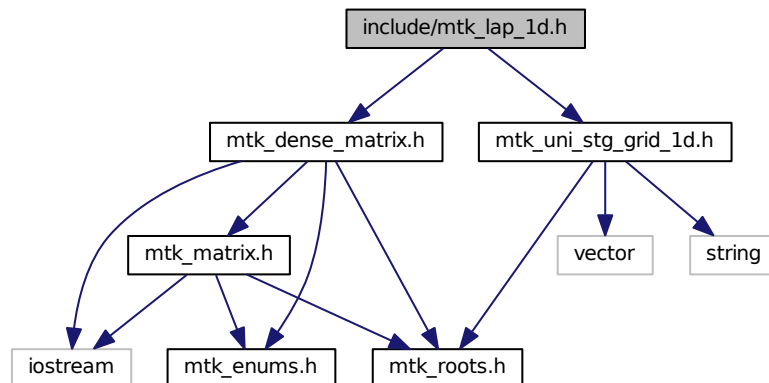
Includes the definition of the class Lap1D.

```

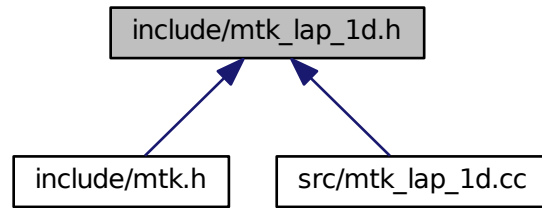
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.31.1 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`.

## 17.32 mtk\_lap\_1d.h

```

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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

```

```

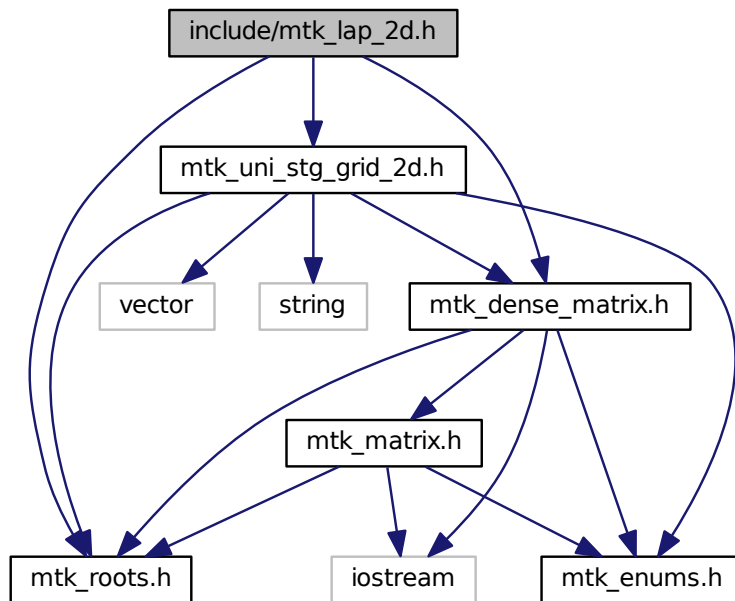
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00055 */
00056
00057 #ifndef MTK_INCLUDE_LAP_1D_H_
00058 #define MTK_INCLUDE_LAP_1D_H_
00059
00060 #include "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     bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00077                        Real mimetic_threshold = kDefaultMimeticThreshold);
00078
00079     DenseMatrix ReturnAsDenseMatrix(const
00080 UniStgGrid1D &grid) const;
00081
00082     const mtk::Real* data(const UniStgGrid1D &grid) const;
00083
00084 private:
00085     int order_accuracy_;
00086     int laplacian_length_;
00087     Real *laplacian_;
00088     Real mimetic_threshold_;
00089 };
00090
00091 #endif // End of: MTK_INCLUDE_LAP_1D_H_

```

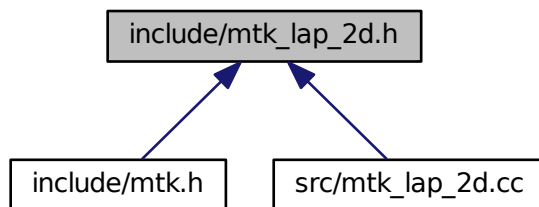
## 17.33 include/mtk\_lap\_2d.h File Reference

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.*

### 17.33.1 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](#).

## 17.34 mtk\_lap\_2d.h

```

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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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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
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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();
00080
00086     Lap2D(const Lap2D &lap);
00087
00089     ~Lap2D();
00090
00096     bool ConstructLap2D(const UniStgGrid2D &grid,
00097                        int order_accuracy = kDefaultOrderAccuracy,
00098                        Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105     DenseMatrix ReturnAsDenseMatrix() const;
00106
00112     Real *data() const;
00113
00114 private:
00115     DenseMatrix laplacian_;
00116
00117     int order_accuracy_;
00118
00119     Real mimetic_threshold_;
00120 };
00121 }
00122 #endif // End of: MTK_INCLUDE_MTK_LAP_2D_H_

```

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

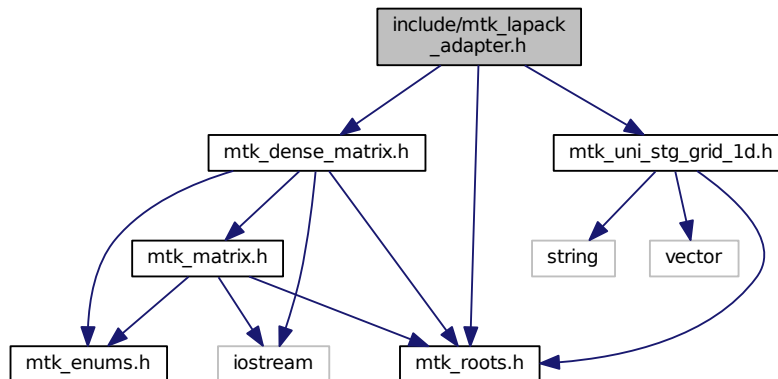
Adapter class for the LAPACK API.

```

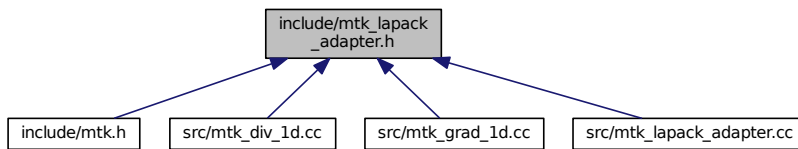
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

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.*

### 17.35.1 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](#).

## 17.36 mtk\_lapack\_adapter.h

```

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```

```

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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00066 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00067
00068 #include "mtk_roots.h"
00069 #include "mtk_dense_matrix.h"
00070 #include "mtk_uni_stg_grid_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_);
00159     static mtk::DenseMatrix QRFactorDenseMatrix(
00160         DenseMatrix &matrix);
00161 }
00162 #endif // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_

```

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

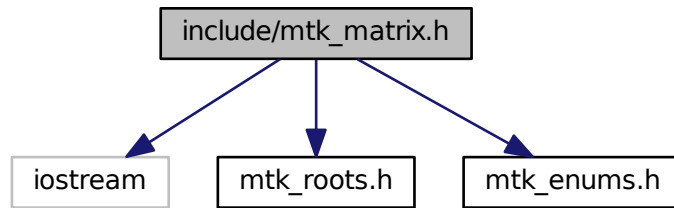
Definition of the representation of a matrix in the MTK.

```

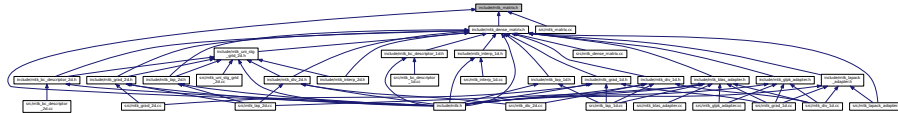
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"

```

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.*

### 17.37.1 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](#).

## 17.38 mtk\_matrix.h

```

00001
00010 /*
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```

```

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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
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00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #ifndef MTK_INCLUDE_MATRIX_H_
00057 #define MTK_INCLUDE_MATRIX_H_
00058
00059 #include <iostream>
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_enums.h"
00063
00064 namespace mtk {
00065
00075 class Matrix {
00076 public:
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;

```

```

00167
00173     int kl() const noexcept;
00174
00180     int ku() const noexcept;
00181
00187     int bandwidth() const noexcept;
00188
00196     Real abs_density() const noexcept;
00197
00205     Real rel_density() const noexcept;
00206
00214     Real abs_sparsity() const noexcept;
00215
00223     Real rel_sparsity() const noexcept;
00224
00232     void set_storage(const MatrixStorage &tt) noexcept;
00233
00241     void set_ordering(const MatrixOrdering &oo) noexcept;
00242
00248     void set_num_rows(const int &num_rows) noexcept;
00249
00255     void set_num_cols(const int &num_cols) noexcept;
00256
00262     void set_num_zero(const int &in) noexcept;
00263
00269     void set_num_null(const int &in) noexcept;
00270
00272     void IncreaseNumZero() noexcept;
00273
00275     void IncreaseNumNull() noexcept;
00276
00277 private:
00278     MatrixStorage storage_;
00279
00280     MatrixOrdering ordering_;
00281
00282     int num_rows_;
00283     int num_cols_;
00284     int num_values_;
00285     int ld_;
00286
00287     int num_zero_;
00288     int num_non_zero_;
00289     int num_null_;
00290     int num_non_null_;
00291
00292     int kl_;
00293     int ku_;
00294     int bandwidth_;
00295
00296     Real abs_density_;
00297     Real rel_density_;
00298     Real abs_sparsity_;
00299     Real rel_sparsity_;
00300 };
00301 }
00302 #endif // End of: MTK_INCLUDE_MATRIX_H_

```

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

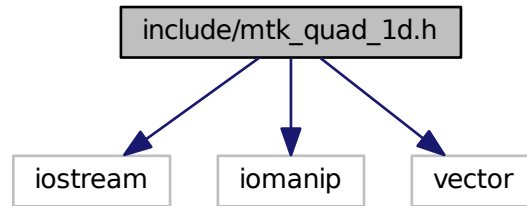
Includes the definition of the class Quad1D.

```

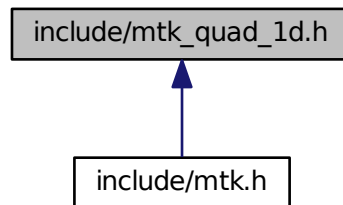
#include <iostream>
#include <iomanip>
#include <vector>

```

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.*

### 17.39.1 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](#).

## 17.40 mtk\_quad\_1d.h

```

00001
00015 /*
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00017 University. All rights reserved.
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00020 are permitted provided that the following conditions are met:
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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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 #ifndef MTK_INCLUDE_QUAD_1D_H_
00062 #define MTK_INCLUDE_QUAD_1D_H_
00063
00064 #include <iostream>
00065 #include <iomanip>
00066
00067 #include <vector>
00068
00069 namespace mtk {
00070
00081 class Quad1D {
00082 public:
00084     friend std::ostream& operator <<(std::ostream& stream, Quad1D &in);
00085
00087     Quad1D();
00088
00094     Quad1D(const Quad1D &quad);
00095

```



```

00097 ~Quad1D();
00098
00104 int degree_approximation() const;
00105
00111 Real *weights() const;
00112
00121 Real Integrate(Real (*Integrand)(Real xx), UniStgGrid1D grid) const;
00122
00123 private:
00124 int degree_approximation_;
00125
00126 std::vector<Real> weights_;
00127 };
00128 }
00129 #endif // End of: MTK_INCLUDE_QUAD_1D_H_

```

## 17.41 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.*

### 17.41.1 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](#).

## 17.42 mtk\_roots.h

```

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00017 /*
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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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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_

```

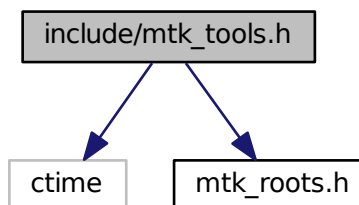
## 17.43 include/mtk\_tools.h File Reference

Tool manager class.

```
#include <ctime>
```

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

Include dependency graph for mtk\_tools.h:





```

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00056 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00057 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00058 */
00059
00060 #ifndef MTK_INCLUDE_TOOLS_H_
00061 #define MTK_INCLUDE_TOOLS_H_
00062
00063 #include <ctime>
00064
00065 #include "mtk_roots.h"
00066
00067 namespace mtk {
00068
00078 class Tools {
00079 public:
00090     static void Prevent(const bool complement,
00091                        const char *const fname,
00092                        int lineno,
00093                        const char *const fxname) noexcept;
00094
00100     static void BeginUnitTestNo(const int &nn) noexcept;
00101
00107     static void EndUnitTestNo(const int &nn) noexcept;
00108
00114     static void Assert(const bool &condition) noexcept;
00115
00116 private:
00117     static int test_number_;
00118
00119     static Real duration_;
00120
00121     static clock_t begin_time_;
00122 };
00123 }
00124 #endif // End of: MTK_INCLUDE_TOOLS_H_

```

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

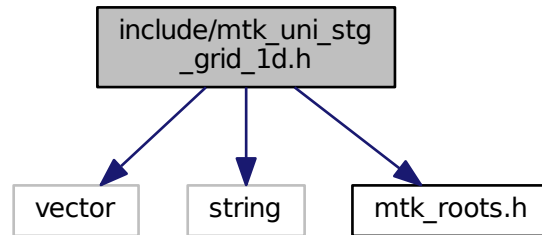
Definition of an 1D uniform staggered grid.

```

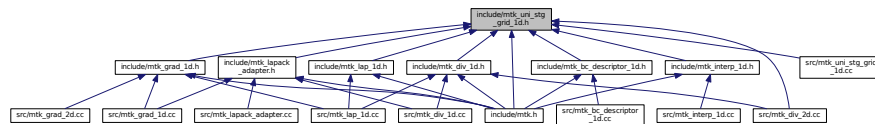
#include <vector>
#include <string>
#include "mtk_roots.h"

```

Include dependency graph for `mtk_uni_stg_grid_1d.h`:



This graph shows which files directly or indirectly include this file:



## Classes

- class [mtk::UniStgGrid1D](#)  
*Uniform 1D Staggered Grid.*

## Namespaces

- [mtk](#)  
*Mimetic Methods Toolkit namespace.*

### 17.45.1 Detailed Description

Definition of an 1D uniform staggered grid.

#### Author

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

**Todo** Create overloaded binding routines that read data from files.

Definition in file [mtk\\_uni\\_stg\\_grid\\_1d.h](#).

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

```

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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
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00034 be given to the copyright holders.
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_1D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_1D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065
00066 namespace mtk {
00067
00077 class UniStgGrid1D {
00078 public:
00080     friend std::ostream& operator <<(std::ostream& stream, UniStgGrid1D &in);
00081
00083     UniStgGrid1D();
00084
00090     UniStgGrid1D(const UniStgGrid1D &grid);
00091
00102     UniStgGrid1D(const Real &west_bndy_x,
00103                  const Real &east_bndy_x,
00104                  const int &num_cells_x,
00105                  const mtk::FieldNature &nature = mtk::SCALAR);
00106
00108     ~UniStgGrid1D();
00109
00115     Real west_bndy_x() const;
00116
00122     Real east_bndy_x() const;
00123
00129     Real delta_x() const;
00130

```

```

00138     const Real *discrete_domain_x() const;
00139
00147     Real *discrete_field_u();
00148
00154     int num_cells_x() const;
00155
00161     void BindScalarField(Real (*ScalarField)(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_u_;
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_

```

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

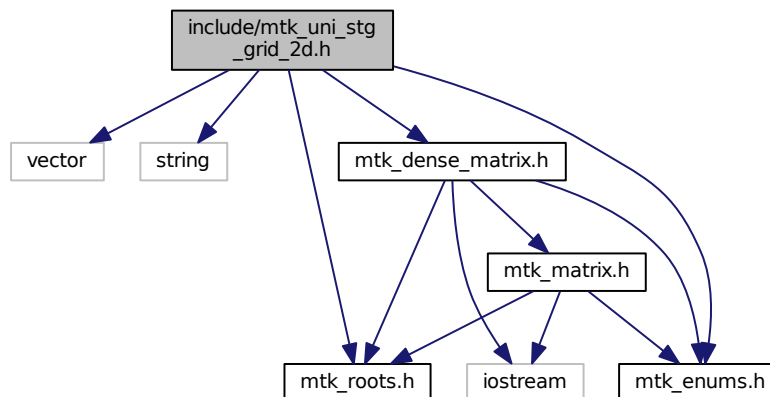
Definition of an 2D uniform staggered grid.

```

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

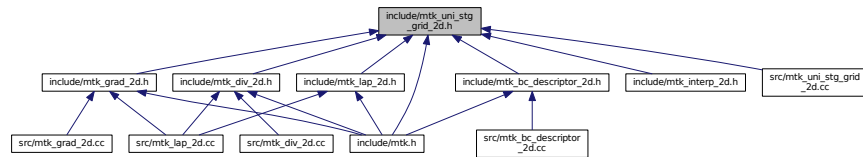
```

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.*

### 17.47.1 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`.

## 17.48 mtk\_uni\_stg\_grid\_2d.h

```

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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
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```

```

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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_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
00070 class UniStgGrid2D {
00071 public:
00072     friend std::ostream& operator <<(std::ostream& stream, UniStgGrid2D &in);
00073
00074     UniStgGrid2D();
00075
00076     UniStgGrid2D(const UniStgGrid2D &grid);
00077
00078     UniStgGrid2D(const Real &west_bndy_x,
00079                  const Real &east_bndy_x,
00080                  const int &num_cells_x,
00081                  const Real &south_bndy_y,
00082                  const Real &north_bndy_y,
00083                  const int &num_cells_y,
00084                  const mtk::FieldNature &nature =
00085                      mtk::SCALAR);
00086
00087     ~UniStgGrid2D();
00088
00089     const Real *discrete_domain_x() const;
00090
00091     const Real *discrete_domain_y() const;
00092
00093     const Real *discrete_field() const;
00094
00095     FieldNature nature() const;
00096
00097     Real west_bndy() const;
00098
00099     Real east_bndy() const;
00100
00101     int num_cells_x() const;
00102
00103     Real delta_x() const;
00104
00105     Real south_bndy() const;
00106
00107     Real north_bndy() const;
00108
00109     int num_cells_y() const;
00110
00111     Real delta_y() const;
00112
00113     bool Bound() const;

```

```

00214
00220 void BindScalarField(Real (*ScalarField)(Real xx, Real yy));
00221
00236 void BindVectorField(Real (*VectorFieldPComponent)(Real xx,
Real yy),
Real (*VectorFieldQComponent)(Real xx,Real yy));
00237
00238
00251 bool WriteToFile(std::string filename,
00252                 std::string space_name_x,
00253                 std::string space_name_y,
00254                 std::string field_name) const;
00255
00256 private:
00269 void BindVectorFieldPComponent(
00270     Real (*VectorFieldPComponent)(Real xx, Real yy));
00271
00284 void BindVectorFieldQComponent(
00285     Real (*VectorFieldQComponent)(Real xx, Real yy));
00286
00287 std::vector<Real> discrete_domain_x_;
00288 std::vector<Real> discrete_domain_y_;
00289 std::vector<Real> discrete_field_;
00290
00291 FieldNature nature_;
00292
00293 Real west_bndy_;
00294 Real east_bndy_;
00295 int num_cells_x_;
00296 Real delta_x_;
00297
00298 Real south_bndy_;
00299 Real north_bndy_;
00300 int num_cells_y_;
00301 Real delta_y_;
00302 };
00303 }
00304 #endif // End of: MTK_INCLUDE_UNI_STG_GRID_2D_H_

```

## 17.49 Makefile.inc File Reference

### 17.50 Makefile.inc

```

00001 # Makefile setup file for 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 # Debug Level. Options are:
00074 # 0. NO debug at all NOR any run-time checks... be cautious!
00075 # 1. Verbose (execution messages) AND run-time checks.
00076 # 2. Level 1 plus intermediate scalar-valued results.
00077 # 3. Level 2 plus intermediate array-valued results.
00078
00079 DEBUG_LEVEL = 3
00080
00081 # Flags recommended for release code:
00082
00083 CFLAGS = -Wall -Werror -O3
00084
00085 # Flags recommended for debugging code:
00086
00087 CFLAGS = -Wall -Werror -g
00088
00089 # 7. Archiver, its flags, and ranlib:
00090 # _____
00091
00092 ARCH = ar
00093 ARCHFLAGS = cr
00094
00095 # If your system does not have "ranlib" then set: "RANLIB = echo":
00096
00097 RANLIB = echo
00098
00099 # But, if possible:
00100
00101 RANLIB = ranlib
00102
00103 # 8. Valgrind's memcheck options (optional):
00104 # _____
00105
00106 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00107 --track-origins=yes --freelist-vol=20000000
00108
00109 # Done! User, please, do not mess with the definitions from this point on.
00110
00111 # _____
00112 # _____
00113 # _____
00114

```

```

00115 #   MTK-related.
00116 #
00117
00118 SRC      = $(BASE)/src
00119 INCLUDE  = $(BASE)/include
00120 LIB      = $(BASE)/lib
00121 MTK_LIB  = $(LIB)/libmtk.a
00122 TESTS    = $(BASE)/tests
00123 EXAMPLES = $(BASE)/examples
00124
00125 #   Compiling-related.
00126 #
00127
00128 CCFLAGS += -std=c++11 -fPIC -DMTK_DEBUG_LEVEL=$(DEBUG_LEVEL) -I$(INCLUDE) -c
00129
00130 ifeq ($(PRECISION),DOUBLE)
00131     CCFLAGS += -DMTK_PRECISION_DOUBLE
00132 else
00133     CCFLAGS += -DMTK_PRECISION_SINGLE
00134 endif
00135
00136 # Only the GLPK is included because the other dependencies are coded in Fortran.
00137
00138 ifeq ($(ATL_OPT),ON)
00139     CCFLAGS += -I$(GLPK_INC) $(ATLAS_INC)
00140 else
00141     CCFLAGS += -I$(GLPK_INC)
00142 endif
00143
00144 #   Linking-related.
00145 #
00146
00147 NOOPT_LIBS = $(LAPACK_LIB) $(BLAS_LIB) -lm $(GLPK_LIB) -lstdc++
00148
00149 OPT_LIBS    = -L$(ATLAS_LIB) -latlas -llapack -lblas -lm -latlas -lstdc++
00150
00151 ifeq ($(PLAT),OSX)
00152     LINKER = g++
00153     LINKER += -framework Accelerate $(GLPK_LIB) $(MTK_LIB)
00154 else
00155     ifeq ($(ATL_OPT),ON)
00156         LINKER = g++
00157         LIBS = $(MTK_LIB)
00158         LIBS += $(OPT_LIBS)
00159     else
00160         LINKER = gfortran
00161         LIBS = $(MTK_LIB)
00162         LIBS += $(NOOPT_LIBS)
00163     endif
00164 endif
00165
00166 #   Documentation-related.
00167 #
00168
00169 DOCGEN      = doxygen
00170 DOCFILENAME = doc_config.dxcf
00171 DOC         = $(BASE)/doc
00172 DOCFILE     = $(BASE)/$(DOCFILENAME)

```

## 17.51 README.md File Reference

### 17.52 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 $(HOME)/Libraries/
00027 ```
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 $ make help
00064 -----
00065 Makefile for the MTK.
00066
00067 Options are:
00068 - all: builds the library, the tests, and examples.
00069 - mtklib: builds the library.
00070 - test: builds the test files.
00071 - example: builds the examples.
00072
00073 - testall: runs all the tests.
00074
00075 - gendoc: generates the documentation for the library.
00076
00077 - clean: cleans all the generated files.
00078 - cleanlib: cleans the generated archive and object files.
00079 - cleantest: cleans the generated tests executables.
00080 - cleanexample: cleans the generated examples executables.
00081
00082 -----
00083 ```
00084
00085 ### PART 2. BUILD THE LIBRARY.
00086 ```
00087 $ make
00088 ```
00089
00090 If successful you'll read (before building the tests and examples):
00091 ```
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 Boada.
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@mail.sdsu.edu - @ejspeiro
00137
00138 Thanks and happy coding!

```

## 17.53 src/mtk\_bc\_descriptor\_1d.cc File Reference

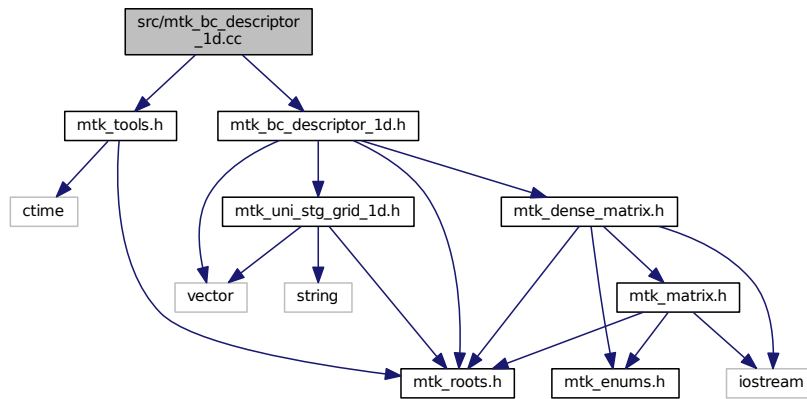
Enforces boundary conditions in either the operator or the grid.

```

#include "mtk_tools.h"
#include "mtk_bc_descriptor_1d.h"

```

Include dependency graph for `mtk_bc_descriptor_1d.cc`:



### 17.53.1 Detailed Description

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

Author

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

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

## 17.54 mtk\_bc\_descriptor\_1d.cc

```

00001
00011 /*
00012 Copyright (C) 2015, Computational Science Research Center, San Diego State
00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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.
00044
00045 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00046 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
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 #include "mtk_tools.h"
00058
00059 #include "mtk_bc_descriptor_1d.h"
00060
00061 void mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(
00062     mtk::DenseMatrix &matrix,
00063     const std::vector<mtk::Real> &west,
00064     const std::vector<mtk::Real> &east) {
00065
00066     #if MTK_DEBUG_LEVEL > 0
00067     mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00068     mtk::Tools::Prevent(west.size() > (unsigned int) matrix.
00069 num_cols(),
00070         __FILE__, __LINE__, __func__);
00071     mtk::Tools::Prevent(east.size() > (unsigned int) matrix.
00072 num_cols(),
00073         __FILE__, __LINE__, __func__);
00074     #endif
00075
00076     for (unsigned int ii = 0; ii < west.size(); ++ii) {
00077         matrix.SetValue(0, ii, west[ii]);
00078     }
00079
00080     for (unsigned int ii = 0; ii < east.size(); ++ii) {
00081         matrix.SetValue(matrix.num_rows() - 1,
00082             matrix.num_cols() - 1 - ii,
00083             east[ii]);
00084     }
00085 }
00086
00087 void mtk::BCDescriptor1D::ImposeOnGrid(
00088     mtk::UniStgGrid1D &grid,
00089     const mtk::Real &omega,
00090     const mtk::Real &epsilon) {
00091
00092     #if MTK_DEBUG_LEVEL > 0
00093     mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00094     #endif
00095
00096     grid.discrete_field_u()[0] = omega;
00097
00098     grid.discrete_field_u()[grid.num_cells_x() + 2 - 1] = epsilon;
00099 }

```

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

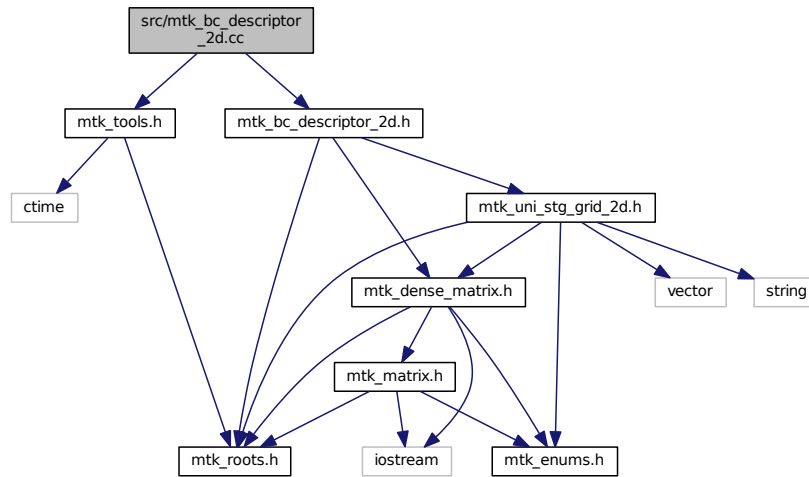
Enforces boundary conditions in either the operator or the grid.

```

#include "mtk_tools.h"
#include "mtk_bc_descriptor_2d.h"

```

Include dependency graph for `mtk_bc_descriptor_2d.cc`:



### 17.55.1 Detailed Description

This class presents an interface for the user to specify boundary conditions on 2D mimetic operators and the grids they are acting on.

**Def.** Let  $f$  be any scalar or vector field defined over a domain  $\Omega$ . We can specify any linear combination of  $f$  and its  $n$  derivatives to fulfill a condition, which we define as a **boundary condition**:

$$\forall \mathbf{x} \in \partial\Omega : \sum_{i=0}^n c_i(\mathbf{x}) < \hat{\mathbf{n}}, \frac{\partial^i f}{\partial x^i}(\mathbf{x}) > = \beta(\mathbf{x}).$$

This class receives information about the highest-order of differentiation,  $n$ , all possible coefficient functions,  $c_i(\mathbf{x})$  for any subset of the boundary (south, north, west and east), and each condition for any subset of the boundary, and takes care of assigning them to both, the differentiation matrices and the grids.

Author

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

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

## 17.56 mtk\_bc\_descriptor\_2d.cc

```

00001
00030 /*
00031 Copyright (C) 2015, Computational Science Research Center, San Diego State
00032 University. All rights reserved.
00033
00034 Redistribution and use in source and binary forms, with or without modification,
00035 are permitted provided that the following conditions are met:
00036
00037 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu

```

```

00038 and a copy of the modified files should be reported once modifications are
00039 completed, unless these modifications are made through the project's GitHub
00040 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00041 should be developed and included in any deliverable.
00042
00043 2. Redistributions of source code must be done through direct
00044 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00045
00046 3. Redistributions in binary form must reproduce the above copyright notice,
00047 this list of conditions and the following disclaimer in the documentation and/or
00048 other materials provided with the distribution.
00049
00050 4. Usage of the binary form on proprietary applications shall require explicit
00051 prior written permission from the the copyright holders, and due credit should
00052 be given to the copyright holders.
00053
00054 5. Neither the name of the copyright holder nor the names of its contributors
00055 may be used to endorse or promote products derived from this software without
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00059 not infringe any patent, copyright, or any other intellectual property rights of
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00070 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00071 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00072 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00073 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00074 */
00075
00076 #include "mtk_tools.h"
00077
00078 #include "mtk_bc_descriptor_2d.h"
00079
00080 mtk::BCDescriptor2D::BCDescriptor2D():
00081     generate_space_(false),
00082     highest_order_diff_west_(-1),
00083     highest_order_diff_east_(-1),
00084     highest_order_diff_south_(-1),
00085     highest_order_diff_north_(-1),
00086     west_condition_(),
00087     east_condition_(),
00088     south_condition_(),
00089     north_condition_() {}
00090
00091 mtk::BCDescriptor2D::BCDescriptor2D(const
00092     mtk::BCDescriptor2D &desc) {}
00093
00094 mtk::BCDescriptor2D::~BCDescriptor2D() noexcept {}
00095
00096 int mtk::BCDescriptor2D::highest_order_diff_west() const
00097     noexcept {
00098     return highest_order_diff_west_;
00099 }
00100
00101 int mtk::BCDescriptor2D::highest_order_diff_east() const
00102     noexcept {
00103     return highest_order_diff_east_;
00104 }
00105
00106 int mtk::BCDescriptor2D::highest_order_diff_south() const
00107     noexcept {
00108     return highest_order_diff_south_;
00109 }
00110
00111 int mtk::BCDescriptor2D::highest_order_diff_north() const
00112     noexcept {
00113     return highest_order_diff_north_;
00114 }

```

```

00114
00115 void mtk::BCDescriptor2D::PushBackWestCoeff(
    mtk::CoefficientFunction2D cw) {
00116
00117     #if MTK_DEBUG_LEVEL > 0
00118     mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00119     mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00120         __FILE__, __LINE__, __func__);
00121     #endif
00122     west_coefficients_.push_back(cw);
00123
00124     highest_order_diff_west_++;
00125 }
00126
00127
00128 void mtk::BCDescriptor2D::PushBackEastCoeff(
    mtk::CoefficientFunction2D ce) {
00129
00130     #if MTK_DEBUG_LEVEL > 0
00131     mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00132     mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00133         __FILE__, __LINE__, __func__);
00134     #endif
00135     east_coefficients_.push_back(ce);
00136
00137     highest_order_diff_east_++;
00138 }
00139
00140
00141 void mtk::BCDescriptor2D::PushBackSouthCoeff(
    mtk::CoefficientFunction2D cs) {
00142
00143     #if MTK_DEBUG_LEVEL > 0
00144     mtk::Tools::Prevent(cs == nullptr, __FILE__, __LINE__, __func__);
00145     mtk::Tools::Prevent(highest_order_diff_south_ > 1,
00146         __FILE__, __LINE__, __func__);
00147     #endif
00148     south_coefficients_.push_back(cs);
00149
00150     highest_order_diff_south_++;
00151 }
00152
00153
00154 void mtk::BCDescriptor2D::PushBackNorthCoeff(
    mtk::CoefficientFunction2D cn) {
00155
00156     #if MTK_DEBUG_LEVEL > 0
00157     mtk::Tools::Prevent(cn == nullptr, __FILE__, __LINE__, __func__);
00158     mtk::Tools::Prevent(highest_order_diff_north_ > 1,
00159         __FILE__, __LINE__, __func__);
00160     #endif
00161     north_coefficients_.push_back(cn);
00162
00163     highest_order_diff_north_++;
00164 }
00165
00166
00167 void mtk::BCDescriptor2D::set_west_condition(
    mtk::Real (*west_condition)(mtk::Real xx, mtk::Real yy)) noexcept {
00168
00169     #if MTK_DEBUG_LEVEL > 0
00170     mtk::Tools::Prevent(west_condition == nullptr, __FILE__, __LINE__, __func__);
00171     #endif
00172     west_condition_ = west_condition;
00173 }
00174
00175
00176
00177 void mtk::BCDescriptor2D::set_east_condition(
    mtk::Real (*east_condition)(mtk::Real xx, mtk::Real yy)) noexcept {
00178
00179     #if MTK_DEBUG_LEVEL > 0
00180     mtk::Tools::Prevent(east_condition == nullptr, __FILE__, __LINE__, __func__);
00181     #endif
00182     east_condition_ = east_condition;
00183 }
00184
00185
00186
00187 void mtk::BCDescriptor2D::set_south_condition(
    mtk::Real (*south_condition)(mtk::Real xx, mtk::Real yy)) noexcept {
00188
00189     #if MTK_DEBUG_LEVEL > 0
00190

```

```

00191     mtk::Tools::Prevent(south_condition == nullptr,
00192                         __FILE__, __LINE__, __func__);
00193     #endif
00194     south_condition_ = south_condition;
00195 }
00196
00197 void mtk::BCDescriptor2D::set_north_condition(
00198     mtk::Real (*north_condition)(mtk::Real xx, mtk::Real yy)) noexcept {
00199     #if MTK_DEBUG_LEVEL > 0
00200     mtk::Tools::Prevent(north_condition_ == nullptr,
00201                         __FILE__, __LINE__, __func__);
00202     #endif
00203     north_condition_ = north_condition;
00204 }
00205
00206 void mtk::BCDescriptor2D::ImposeOnSouthBoundary(
00207     const mtk::UniStgGrid2D &grid,
00208     mtk::DenseMatrix &matrix,
00209     const int &order_accuracy) const {
00210     // At this point we have all of the information we need to fully impose the
00211     // south boundary condition:
00212     // 1. We have the collection of coefficients. The size of this collection
00213     // tells us the type of BC for this boundary.
00214     // 2. We have the grid that we can use to evaluate the coefficients at.
00215     // 3. We have the matrix where to place them.
00216
00217     // For now, we are sure that we will NOT have more than 2 coefficients per
00218     // boundary. That is, we only support Robin type FOR NOW.
00219
00220     if (generate_space_) {
00221         // For the south-west corner:
00222         auto cc = (south_coefficients_[0])(grid.west_bndy(), grid.
00223             south_bndy());
00224
00225         #if MTK_DEBUG_LEVEL > 0
00226         std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00227             matrix.num_cols() << " columns." << std::endl;
00228         std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00229         #endif
00230         matrix.SetValue(0, 0, cc);
00231
00232         // Compute first centers per dimension.
00233         auto first_center_x = grid.west_bndy() + grid.delta_x()/
00234             mtk::kTwo;
00235
00236         // For each entry on the diagonal (south boundary):
00237         for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00238             // Evaluate next set spatial coordinates to evaluate the coefficient.
00239             mtk::Real xx = first_center_x + ii*grid.delta_x();
00240             // Evaluate and assign the Dirichlet coefficient.
00241             cc = (south_coefficients_[0])(xx, grid.south_bndy());
00242
00243             #if MTK_DEBUG_LEVEL > 0
00244             std::cout << "Setting at " << ii + 1 << ' ' << ii + 1 << std::endl;
00245             #endif
00246             matrix.SetValue(ii + 1, ii + 1, cc);
00247         }
00248
00249         // For the south-east corner:
00250         cc = (south_coefficients_[0])(grid.east_bndy(), grid.south_bndy());
00251
00252         #if MTK_DEBUG_LEVEL > 0
00253         std::cout << "Setting at " << grid.num_cells_x() + 1 << ' ' <<
00254             grid.num_cells_x() + 1 << std::endl;
00255         #endif
00256         matrix.SetValue(grid.num_cells_x() + 1, grid.num_cells_x() + 1, cc);
00257     } else {
00258         // For each entry on the diagonal:

```

```

00274     for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00275         // Evaluate next set spatial coordinates to evaluate the coefficient.
00276         mtk::Real xx{(grid.discrete_domain_x())[ii]};
00277         // Evaluate and assign the Dirichlet coefficient.
00278         mtk::Real cc = (south_coefficients_[0])(xx, grid.south_bndy());
00279         matrix.SetValue(ii, ii, cc);
00280     }
00281 }
00282 }
00283 }
00284 }
00285
00286 void mtk::BCDescriptor2D::ImposeOnNorthBoundary(
00287     const mtk::UniStgGrid2D &grid,
00288     mtk::DenseMatrix &matrix,
00289     const int &order_accuracy) const {
00290
00291     // At this point we have all of the information we need to fully impose the
00292     // north boundary condition:
00293     // 1. We have the collection of coefficients. The size of this collection
00294     // tells us the type of BC for this boundary.
00295     // 2. We have the grid that we can use to evaluate the coefficients at.
00296     // 3. We have the matrix where to place them.
00297
00298     // For now, we are sure that we will NOT have more than 2 coefficients per
00299     // boundary. That is, we only support Robin type FOR NOW.
00300
00301     int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00302
00303     if (generate_space_) {
00304
00305         // For the north-west corner:
00306         mtk::Real cc =
00307             (north_coefficients_[0])(grid.west_bndy(), grid.north_bndy());
00308
00309         #if MTK_DEBUG_LEVEL > 0
00310             std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00311                 matrix.num_cols() << " columns." << std::endl;
00312             std::cout << "Setting at " << north_offset << ' ' << north_offset <<
00313                 std::endl;
00314         #endif
00315
00316         matrix.SetValue(north_offset, north_offset, cc);
00317
00318         // Compute first centers per dimension.
00319         auto first_center_x = grid.west_bndy() + grid.delta_x()/
00320             mtk::kTwo;
00321
00322         // For each entry on the diagonal (north boundary):
00323         for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00324             // Evaluate next set spatial coordinates to evaluate the coefficient.
00325             mtk::Real xx = first_center_x + ii*grid.delta_x();
00326             // Evaluate and assign the Dirichlet coefficient.
00327             cc = (north_coefficients_[0])(xx, grid.north_bndy());
00328
00329             #if MTK_DEBUG_LEVEL > 0
00330                 std::cout << "Setting at " << north_offset + ii + 1 << ' ' <<
00331                     north_offset + ii + 1 << std::endl;
00332             #endif
00333
00334             matrix.SetValue(north_offset + ii + 1, north_offset + ii + 1, cc);
00335         }
00336
00337         // For the north-east corner:
00338         cc = (north_coefficients_[0])(grid.east_bndy(), grid.north_bndy());
00339
00340         #if MTK_DEBUG_LEVEL > 0
00341             std::cout << "Setting at " << north_offset + grid.num_cells_x() + 1 <<
00342                 ' ' << north_offset + grid.num_cells_x() + 1 << std::endl;
00343         #endif
00344
00345         matrix.SetValue(north_offset + grid.num_cells_x() + 1,
00346             north_offset + grid.num_cells_x() + 1, cc);
00347     } else {
00348
00349         // For each entry on the diagonal:
00350         for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00351             // Evaluate next set spatial coordinates to evaluate the coefficient.
00352             mtk::Real xx{(grid.discrete_domain_x())[ii]};

```

```

00358     // Evaluate and assign the Dirichlet coefficient.
00359     mtk::Real cc = (north_coefficients_[0])(xx, grid.north_bndy());
00360     matrix.SetValue(north_offset + ii, north_offset + ii, cc);
00361 }
00362 }
00363 }
00364 }
00365 }
00366
00367 void mtk::BCDescriptor2D::ImposeOnWestBoundary(
00368     const mtk::UniStgGrid2D &grid,
00369     mtk::DenseMatrix &matrix,
00370     const int &order_accuracy) const {
00371
00372     // At this point we have all of the information we need to fully impose the
00373     // west boundary condition:
00374     // 1. We have the collection of coefficients. The size of this collection
00375     // tells us the type of BC for this boundary.
00376     // 2. We have the grid that we can use to evaluate the coefficients at.
00377     // 3. We have the matrix where to place them.
00378
00379     if (generate_space_) {
00380
00381         // For the south-west corner:
00382         auto cc = (west_coefficients_[0])(grid.west_bndy(), grid.south_bndy());
00383
00384         #if MTK_DEBUG_LEVEL > 0
00385         std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00386             matrix.num_cols() << " columns." << std::endl;
00387         std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00388         #endif
00389
00390         matrix.SetValue(0, 0, (matrix.GetValue(0, 0) + cc)/mtk::kTwo);
00391
00392         int west_offset{grid.num_cells_x() + 1};
00393
00394         auto first_center_y = grid.south_bndy() + grid.delta_y()/
00395             mtk::kTwo;
00396
00397         // For each west entry on the diagonal (west boundary):
00398         for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00399             // Evaluate next set spatial coordinates to evaluate the coefficient.
00400             mtk::Real yy = first_center_y + ii*grid.delta_y();
00401             // Evaluate and assign the Dirichlet coefficient.
00402             cc = (west_coefficients_[0])(grid.west_bndy(), yy);
00403
00404             #if MTK_DEBUG_LEVEL > 0
00405             std::cout << "Setting at " << west_offset + ii + 1 << ' ' <<
00406                 west_offset + ii + 1 << std::endl;
00407             #endif
00408
00409             matrix.SetValue(west_offset + ii + 1, west_offset + ii + 1, cc);
00410
00411             west_offset += grid.num_cells_x() + 1;
00412         }
00413
00414         // For the north-west corner:
00415         cc = (west_coefficients_[0])(grid.west_bndy(), grid.north_bndy());
00416
00417         west_offset += grid.num_cells_x() + 1;
00418         int aux{west_offset};
00419         #if MTK_DEBUG_LEVEL > 0
00420         std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00421         #endif
00422         matrix.SetValue(aux, aux, (matrix.GetValue(aux, aux) + cc)/
00423             mtk::kTwo);
00424     } else {
00425
00426         int west_offset{grid.num_cells_x() + 1};
00427         // For each west entry on the diagonal:
00428         for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00429             // Evaluate next set spatial coordinates to evaluate the coefficient.
00430             mtk::Real yy{grid.discrete_domain_y()[ii]};
00431             // Evaluate and assign the Dirichlet coefficient.
00432             mtk::Real cc = (west_coefficients_[0])(grid.west_bndy(), yy);
00433             mtk::Real aux =
00434                 (matrix.GetValue(west_offset + ii, west_offset + ii) + cc)/
00435                 mtk::kTwo;
00436             matrix.SetValue(west_offset + ii, west_offset + ii, aux);
00437         }
00438     }
00439 }

```

```

00443     west_offset += grid.num_cells_x() + 1;
00444 }
00445
00447 }
00448 }
00449
00450 void mtk::BCDescriptor2D::ImposeOnEastBoundary(
00451     const mtk::UniStgGrid2D &grid,
00452     mtk::DenseMatrix &matrix,
00453     const int &order_accuracy) const {
00454
00455     // At this point we have all of the information we need to fully impose the
00456     // east boundary condition:
00457     // 1. We have the collection of coefficients. The size of this collection
00458     // tells us the type of BC for this boundary.
00459     // 2. We have the grid that we can use to evaluate the coefficients at.
00460     // 3. We have the matrix where to place them.
00461
00462     if (generate_space_) {
00463
00464         // For the south-east corner:
00465         auto cc = (east_coefficients_[0])(grid.east_bndy(), grid.south_bndy());
00466
00467         int east_offset{grid.num_cells_x() + 1};
00468         #if MTK_DEBUG_LEVEL > 0
00469         std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00470             matrix.num_cols() << " columns." << std::endl;
00471         std::cout << "Setting at " << east_offset << ' ' << east_offset <<
00472             std::endl;
00473         #endif
00474         matrix.SetValue(east_offset,
00475             east_offset,
00476             (matrix.GetValue(east_offset, east_offset) + cc)/
00477             mtk::kTwo);
00478
00479         auto first_center_y = grid.south_bndy() + grid.delta_y()/
00480             mtk::kTwo;
00481
00482         // For each east entry on the diagonal (east boundary):
00483         for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00484             east_offset += grid.num_cells_x() + 1;
00485
00486             // Evaluate next set spatial coordinates to evaluate the coefficient.
00487             mtk::Real yy = first_center_y + ii*grid.delta_y();
00488             // Evaluate and assign the Dirichlet coefficient.
00489             cc = (east_coefficients_[0])(grid.east_bndy(), yy);
00490
00491             #if MTK_DEBUG_LEVEL > 0
00492             std::cout << "Setting at " << east_offset + ii + 1 << ' ' <<
00493                 east_offset + ii + 1 << std::endl;
00494             #endif
00495             matrix.SetValue(east_offset + ii + 1, east_offset + ii + 1, cc);
00496         }
00497
00498         // For the north-east corner:
00499         cc = (east_coefficients_[0])(grid.east_bndy(), grid.north_bndy());
00500
00501         east_offset += grid.num_cells_x() + 1;
00502         east_offset += grid.num_cells_x() + 1;
00503         int aux{east_offset};
00504         #if MTK_DEBUG_LEVEL > 0
00505         std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00506         #endif
00507         matrix.SetValue(aux, aux, (matrix.GetValue(aux, aux) + cc)/
00508             mtk::kTwo);
00509
00510     } else {
00511
00512         int east_offset{grid.num_cells_x() + 1};
00513         // For each west entry on the diagonal:
00514         for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00515             east_offset += grid.num_cells_x() + 1;
00516             // Evaluate next set spatial coordinates to evaluate the coefficient.
00517             mtk::Real yy{(grid.discrete_domain_y())[ii]};
00518             // Evaluate and assign the Dirichlet coefficient.

```



```

00525         mtk::Real cc = (east_coefficients_[0])(grid.east_bndy(), yy);
00526         mtk::Real aux =
00527             (matrix.GetValue(east_offset + ii, east_offset + ii) + cc)/
            mtk::kTwo;
00528         matrix.SetValue(east_offset + ii, east_offset + ii, aux);
00529     }
00530
00531 }
00532
00533 }
00534 }
00535
00536 void mtk::BCDescriptor2D::ImposeOnLaplacianMatrix(
00537     const mtk::UniStgGrid2D &grid,
00538     mtk::DenseMatrix &matrix,
00539     const int &order_accuracy) const {
00540
00541     #if MTK_DEBUG_LEVEL > 0
00542     mtk::Tools::Prevent(highest_order_diff_south_ == -1,
00543         __FILE__, __LINE__, __func__);
00544     mtk::Tools::Prevent(highest_order_diff_north_ == -1,
00545         __FILE__, __LINE__, __func__);
00546     mtk::Tools::Prevent(highest_order_diff_west_ == -1,
00547         __FILE__, __LINE__, __func__);
00548     mtk::Tools::Prevent(highest_order_diff_east_ == -1,
00549         __FILE__, __LINE__, __func__);
00550     mtk::Tools::Prevent(grid.nature() != mtk::SCALAR,
00551         __FILE__, __LINE__, __func__);
00552     mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00553     mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00554     mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00555     mtk::Tools::Prevent(matrix.num_cols() == 0, __FILE__, __LINE__, __func__);
00556     #endif
00557
00558     generate_space_ = !grid.Bound();
00559
00560     ImposeOnSouthBoundary(grid, matrix, order_accuracy);
00561
00562     ImposeOnNorthBoundary(grid, matrix, order_accuracy);
00563
00564     ImposeOnWestBoundary(grid, matrix, order_accuracy);
00565
00566     ImposeOnEastBoundary(grid, matrix, order_accuracy);
00567 }
00568
00569 void mtk::BCDescriptor2D::ImposeOnGrid(
00570     mtk::UniStgGrid2D &grid) const {
00571
00572     #if MTK_DEBUG_LEVEL > 0
00573     mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00574     mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00575     #endif
00576
00577 }
00578
00579 }

```

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

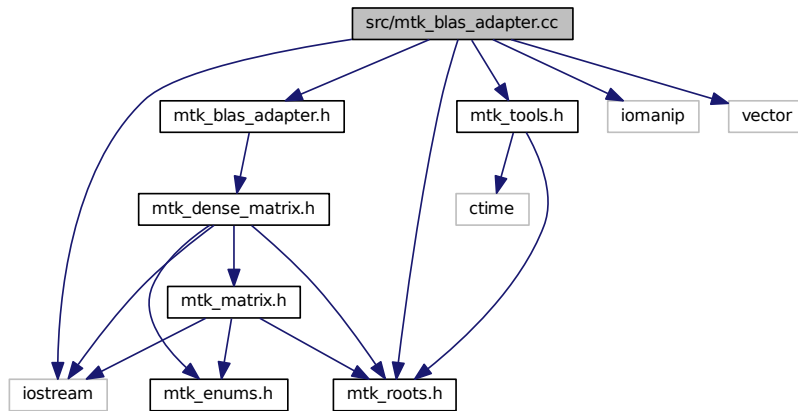
Adapter class for the BLAS API.

```

#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)

### 17.57.1 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

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

## 17.58 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
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00051
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00057
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00060 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00061 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00062 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00063 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00064 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #include <iostream>
00071 #include <iomanip>
00072
00073 #include <vector>
00074
00075 #include "mtk_roots.h"
00076 #include "mtk_tools.h"
00077 #include "mtk_blas_adapter.h"
00078
00079 namespace mtk {
00080
00081 extern "C" {
00082
00083 #ifdef MTK_PRECISION_DOUBLE
00084
00097 double 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     #if MTK_DEBUG_LEVEL > 0
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 dnrms2_(&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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
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     }
00392
00393     char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00394
00395     int mm{aa.num_rows()}; // Rows of aa.
00396     int nn{aa.num_cols()}; // Columns of aa.
00397     int lda{(aa.matrix_properties()).ld()}; // Leading dimension.
00398     int incx{1}; // Increment of values in x.
00399     int incy{1}; // Increment of values in y.
00400
00401     std::swap(mm, nn);
00402     #ifdef MTK_PRECISION_DOUBLE
00403     dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00404           xx, &incx, &beta, yy, &incy);
00405     #else
00406     sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00407           xx, &incx, &beta, yy, &incy);
00408     #endif
00409     std::swap(mm, nn);
00410
00411     mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
00412         mtk::DenseMatrix &aa,
00413         mtk::DenseMatrix &bb) {

```

```

00411
00412 #if MTK_DEBUG_LEVEL > 0
00413 mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00414                     __FILE__, __LINE__, __func__);
00415 #endif
00416
00417 // Make sure input matrices are row-major ordered.
00418
00419 if (aa.matrix_properties().ordering() ==
mtk::COL_MAJOR) {
00420     aa.OrderRowMajor();
00421 }
00422 if (bb.matrix_properties().ordering() ==
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{1.0}; // First scalar coefficient.
00441 mtk::Real beta{0.0}; // 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_DEBUG_LEVEL > 0
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 }

```

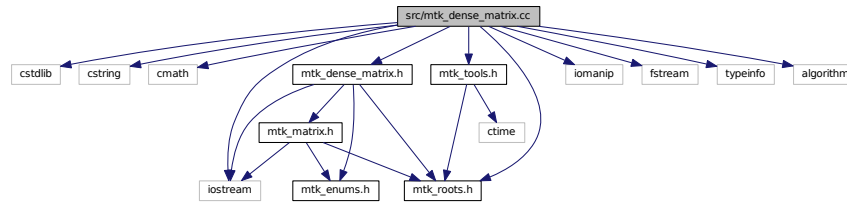
## 17.59 src/mtk\_dense\_matrix.cc File Reference

```

#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)`

## 17.60 mtk\_dense\_matrix.cc

```

00001
00013 /*
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00024 should be developed and included in any deliverable.
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```

```

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00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #include <cstdlib>
00060 #include <cstring>
00061 #include <cmath>
00062
00063 #include <iostream>
00064 #include <iomanip>
00065 #include <fstream>
00066
00067 #include <typeinfo>
00068
00069 #include <algorithm>
00070
00071 #include "mtk_roots.h"
00072 #include "mtk_dense_matrix.h"
00073 #include "mtk_tools.h"
00074
00075 namespace mtk {
00076
00077 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00078
00079     int mm{in.matrix_properties_.num_rows()}; // Auxiliary.
00080     int nn{in.matrix_properties_.num_cols()}; // Auxiliary.
00081
00082     if (in.matrix_properties_.ordering() ==
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
00101 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
00102 mtk::DenseMatrix &in) {
00103
00104     if(this == &in) {
00105         return *this;
00106     }
00107
00108     matrix_properties_.set_storage(in.
00109 matrix_properties_.storage());
00110
00111     matrix_properties_.set_ordering(in.
00112 matrix_properties_.ordering());
00113
00114     auto aux = in.matrix_properties_.num_rows();
00115     matrix_properties_.set_num_rows(aux);
00116
00117     aux = in.matrix_properties().num_cols();
00118     matrix_properties_.set_num_cols(aux);
00119
00120     aux = in.matrix_properties().num_zero();
00121     matrix_properties_.set_num_zero(aux);
00122
00123     aux = in.matrix_properties().num_null();
00124     matrix_properties_.set_num_null(aux);
00125
00126     auto num_rows = matrix_properties_.num_rows();
00127     auto num_cols = matrix_properties_.num_cols();
00128
00129     delete [] data_;
00130
00131     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     #if MTK_DEBUG_LEVEL > 0

```

```

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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
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 void mtk::DenseMatrix::SetValue(
    const int &mm,
    const int &nn,

```

```

00363     const mtk::Real &val) noexcept {
00364
00365     #if MTK_DEBUG_LEVEL > 0
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     }
00443 }

```

```

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 }

```

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

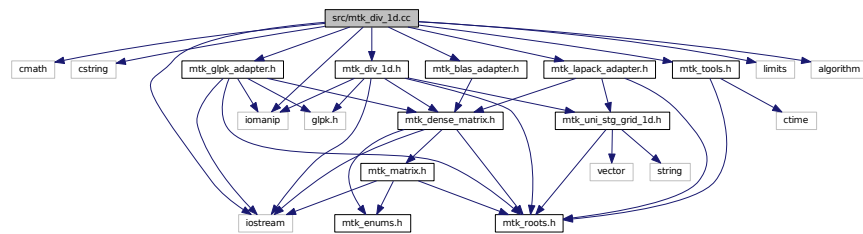
Implements the class Div1D.

```

#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)`

### 17.61.1 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](#).

## 17.62 mtk\_div\_1d.cc

```
00001
00015 /*
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00018
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00023 and a copy of the modified files should be reported once modifications are
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00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
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_ld.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::DivLD &in) {
00080
00081
00082     stream << "divergence_[0] = " << std::setw(9) << in.divergence_[0] <<
00083         std::endl;
00084
00085     stream << "divergence_[1:" << in.order_accuracy_ << "] = ";
00086     for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00087         stream << std::setw(9) << in.divergence_[ii] << " ";
00088     }
00089     stream << std::endl;
00090
00091     if (in.order_accuracy_ > 2) {
00092
00093         stream << "divergence_[ " << in.order_accuracy_ + 1 << ":" <<
00094             2*in.order_accuracy_ << "] = ";
00095         for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
00096             order_accuracy_; ++ii) {
00097             stream << std::setw(9) << in.divergence_[ii] << " ";
00098         }
00099         stream << std::endl;
00100
00101         auto offset = (2*in.order_accuracy_ + 1);
00102         int mm{};
00103         for (auto ii = 0; ii < in.dim_null_; ++ii) {
00104             stream << "divergence_[ " << offset + mm << ":" <<
00105                 offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00106             for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00107                 auto value = in.divergence_[offset + mm];
00108                 stream << std::setw(9) << value << " ";
00109                 ++mm;
00110             }
00111             stream << std::endl;
00112         }
00113     }
00114 }
00115
00116 return stream;
00117 }
00118
00119 }
00120
00121 mtk::DivLD::DivLD():
00122     order_accuracy_(mtk::kDefaultOrderAccuracy),
00123     dim_null_(),
00124     num_bndy_coeffs_(),
00125     divergence_length_(),
00126     minrow_(),
00127     row_(),
00128     coeffs_interior_(),
00129     prem_apps_(),
00130     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     #if MTK_DEBUG_LEVEL > 0
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     bool abort_construction = ComputeStencilInteriorGrid();
00198
00199     #if MTK_DEBUG_LEVEL > 0
00200     if (!abort_construction) {
00201         std::cerr << "Could NOT complete stage 1." << std::endl;
00202         std::cerr << "Exiting..." << std::endl;
00203         return false;
00204     }
00205     #endif
00206
00207     // At this point, we already have the values for the interior stencil stored
00208     // in the coeffs_interior_ array.
00209
00210     // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00211     // approximation at the boundary, thus it has no weights. For this case, the
00212     // dimension of the null-space of the Vandermonde matrices used to compute the
00213     // approximating coefficients at the boundary is 0. Ergo, we compute this
00214     // number first and then decide if we must compute anything at the boundary.
00215
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       #if MTK_DEBUG_LEVEL > 0
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       #if MTK_DEBUG_LEVEL > 0
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       #if MTK_DEBUG_LEVEL > 0
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       #if MTK_DEBUG_LEVEL > 0
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   // Once we have the following three collections of data:
00295   //   (a) the coefficients for the interior,
00296   //   (b) the coefficients for the boundary (if it applies),
00297   //   (c) and the weights (if it applies),
00298   // we will store everything in the output array:
00299
00300   abort_construction = AssembleOperator();
00301
00302

```

```

00303
00304 #if MTK_DEBUG_LEVEL > 0
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
00336 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00337     mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00338
00339     auto counter = 0;
00340     for (auto ii = 0; ii < dim_null_; ++ii) {
00341         for (auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00342             xx.SetValue(ii, jj, divergence_[2*order_accuracy_ + 1 + counter]);
00343             counter++;
00344         }
00345     }
00346     return xx;
00347 }
00348
00349
00350
00351 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(
00352     const UniStgGrid1D &grid) const {
00353     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00354
00355     #if MTK_DEBUG_LEVEL > 0
00356     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00357     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00358     #endif
00359
00360     mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00361
00362     int dd_num_rows = nn + 2;
00363     int dd_num_cols = nn + 1;
00364     int elements_per_row = num_bndy_coeffs_;
00365     int num_extra_rows = dim_null_;
00366
00367     // Output matrix featuring sizes for divergence operators.
00368     mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00369
00370
00371
00372     auto ee_index = 0;
00373     for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00374         auto cc = 0;
00375         for (auto jj = 0; jj < dd_num_rows; jj++) {
00376             if (cc >= elements_per_row) {
00377                 out.SetValue(ii, jj, mtk::kZero);
00378             } else {
00379                 out.SetValue(ii, jj, mim_bndy_[ee_index++] * inv_delta_x);
00380                 cc++;
00381             }
00382         }
00383     }
00384 }

```

```

00385
00387
00388     for (auto ii = num_extra_rows + 1;
00389          ii < dd_num_rows - num_extra_rows - 1; ii++) {
00390         auto jj = ii - num_extra_rows - 1;
00391         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00392             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00393         }
00394     }
00395
00397
00398     ee_index = 0;
00399     for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--) {
00400         auto cc = 0;
00401         for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00402             if (cc >= elements_per_row) {
00403                 out.SetValue(ii, jj, 0.0);
00404             } else {
00405                 out.SetValue(ii, jj, -mim_bndy_[ee_index++] * inv_delta_x);
00406                 cc++;
00407             }
00408         }
00409     }
00410
00411     return out;
00412 }
00413
00414 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00415
00417
00418     mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00419
00420     try {
00421         pp = new mtk::Real[order_accuracy_];
00422     } catch (std::bad_alloc &memory_allocation_exception) {
00423         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00424             std::endl;
00425         std::cerr << memory_allocation_exception.what() << std::endl;
00426     }
00427     memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00428
00429     #ifdef MTK_PRECISION_DOUBLE
00430     pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00431     #else
00432     pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00433     #endif
00434
00435     for (auto ii = 1; ii < order_accuracy_; ++ii) {
00436         pp[ii] = pp[ii - 1] + mtk::kOne;
00437     }
00438
00439     #if MTK_DEBUG_LEVEL > 0
00440     std::cout << "pp = " << std::endl;
00441     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00442         std::cout << std::setw(12) << pp[ii];
00443     }
00444     std::cout << std::endl << std::endl;
00445     #endif
00446
00447
00448     bool transpose{false};
00449
00450     mtk::DenseMatrix vander_matrix(pp,
00451                                     order_accuracy_,
00452                                     order_accuracy_,
00453                                     transpose);
00454
00455     #if MTK_DEBUG_LEVEL > 0
00456     std::cout << "vander_matrix = " << std::endl;
00457     std::cout << vander_matrix << std::endl;
00458     #endif
00459
00460
00461     try {
00462         coeffs_interior_ = new mtk::Real[order_accuracy_];
00463     } catch (std::bad_alloc &memory_allocation_exception) {
00464         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00465             std::endl;
00466         std::cerr << memory_allocation_exception.what() << std::endl;
00467     }
00468
00469     memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00470

```

```

00471
00472     coeffs_interior_[1] = mtk::kOne;
00473
00474     #if MTK_DEBUG_LEVEL > 0
00475     std::cout << "oo =" << std::endl;
00476     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00477         std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00478     }
00479     std::cout << std::endl;
00480     #endif
00481
00482
00483
00484     int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00485                                                    coeffs_interior_)};
00486
00487     #if MTK_DEBUG_LEVEL > 0
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_DEBUG_LEVEL > 0
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
00518
00519     try {
00520         gg = new mtk::Real[num_bndy_coeffs_];
00521     } catch (std::bad_alloc &memory_allocation_exception) {
00522         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00523             std::endl;
00524         std::cerr << memory_allocation_exception.what() << std::endl;
00525     }
00526     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00527
00528     #ifdef MTK_PRECISION_DOUBLE
00529     gg[0] = -1.0/2.0;
00530     #else
00531     gg[0] = -1.0f/2.0f;
00532     #endif
00533     for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00534         gg[ii] = gg[ii - 1] + mtk::kOne;
00535     }
00536
00537     #if MTK_DEBUG_LEVEL > 0
00538     std::cout << "gg =" << std::endl;
00539     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00540         std::cout << std::setw(12) << gg[ii];
00541     }
00542     std::cout << std::endl << std::endl;
00543     #endif
00544
00545
00546
00547     bool tran{true}; // Should I transpose the Vandermonde matrix.
00548
00549     mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00550
00551     #if MTK_DEBUG_LEVEL > 0
00552     std::cout << "vv_west_t =" << std::endl;
00553     std::cout << vv_west_t << std::endl;
00554     #endif

```

```

00555
00557
00558   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
(vv_west_t));
00559
00560   #if MTK_DEBUG_LEVEL > 0
00561   std::cout << "QQ^T = " << std::endl;
00562   std::cout << qq_t << std::endl;
00563   #endif
00564
00565
00566
00567   int KK_num_rows_{num_bndy_coeffs_};
00568   int KK_num_cols_{dim_null_};
00569
00570   mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00571
00572   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00573       for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00574           KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00575               qq_t.data()[ii*num_bndy_coeffs_ + jj];
00576       }
00577   }
00578
00579   #if MTK_DEBUG_LEVEL > 0
00580   std::cout << "KK =" << std::endl;
00581   std::cout << KK << std::endl;
00582   std::cout << "KK.num_rows() = " << KK.num_rows() << std::endl;
00583   std::cout << "KK.num_cols() = " << KK.num_cols() << std::endl;
00584   std::cout << std::endl;
00585   #endif
00586
00587
00588
00589   // Scale thus requesting that the last entries of the attained basis for the
00590   // null-space, adopt the pattern we require.
00591   // Essentially we will implement the following MATLAB pseudo-code:
00592   // scalars = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00593   // SK = KK*scalars
00594   // where SK is the scaled null-space.
00595
00596   // In this point, we almost have all the data we need correctly allocated
00597   // in memory. We will create the matrix II_, and elements we wish to scale in
00598   // the KK array. Using the concept of the leading dimension, we could just
00599   // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00600   // GET how does it work. So I will just create a matrix with the content of
00601   // this array that we need, solve for the scalars and then scale the
00602   // whole KK:
00603
00604   // We will then create memory for that sub-matrix of KK (SUBK).
00605
00606   mtk::DenseMatrix SUBK(dim_null_,dim_null_);
00607
00608   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00609       for (auto jj = 0; jj < dim_null_; ++jj) {
00610           SUBK.data()[ (ii - (num_bndy_coeffs_ - dim_null_))*dim_null_ + jj] =
00611               KK.data()[ii*dim_null_ + jj];
00612       }
00613   }
00614
00615   #if MTK_DEBUG_LEVEL > 0
00616   std::cout << "SUBK =" << std::endl;
00617   std::cout << SUBK << std::endl;
00618   #endif
00619
00620   SUBK.Transpose();
00621
00622   #if MTK_DEBUG_LEVEL > 0
00623   std::cout << "SUBK^T =" << std::endl;
00624   std::cout << SUBK << std::endl;
00625   #endif
00626
00627   bool padded{false};
00628   tran = false;
00629
00630   mtk::DenseMatrix II(dim_null_, padded, tran);
00631
00632   #if MTK_DEBUG_LEVEL > 0
00633   std::cout << "II =" << std::endl;
00634   std::cout << II << std::endl;
00635   #endif
00636
00637   // Solve the system to compute the scalars.

```

```

00638 // An example of the system to solve, for k = 8, is:
00639 //
00640 // SUBK*scalers = II_ or
00641 //
00642 // | 0.386018 -0.0339244 -0.129478 | | 1 0 0 |
00643 // | -0.119774 0.0199423 0.0558632 |*scalers = | 0 1 0 |
00644 // | 0.0155708 -0.00349546 -0.00853182 | | 0 0 1 |
00645 //
00646 // Notice this is a nrhs = 3 system.
00647 // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalars... they
00648 // will be stored in the created identity matrix.
00649 // Let us first transpose SUBK (because of LAPACK):
00650
00651 int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00652
00653 #if MTK_DEBUG_LEVEL > 0
00654 if (!info) {
00655     std::cout << "System successfully solved!" <<
00656         std::endl;
00657 } else {
00658     std::cerr << "Something went wrong solving system! info = " << info <<
00659         std::endl;
00660     std::cerr << "Exiting..." << std::endl;
00661     return false;
00662 }
00663 std::cout << std::endl;
00664 #endif
00665
00666 #if MTK_DEBUG_LEVEL > 0
00667 std::cout << "Computed scalars:" << std::endl;
00668 std::cout << II << std::endl;
00669 #endif
00670
00671 // Multiply the two matrices to attain a scaled basis for null-space.
00672
00673 rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00674
00675 #if MTK_DEBUG_LEVEL > 0
00676 std::cout << "Rational basis for the null-space:" << std::endl;
00677 std::cout << rat_basis_null_space_ << std::endl;
00678 #endif
00679
00680 // At this point, we have a rational basis for the null-space, with the
00681 // pattern we need! :)
00682
00683 delete [] gg;
00684 gg = nullptr;
00685
00686 return true;
00687 }
00688
00689 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00690
00691     mtk::Real *gg{}; // Generator vector for the first approximation.
00692
00693     try {
00694         gg = new mtk::Real[num_bndy_coeffs_];
00695     } catch (std::bad_alloc &memory_allocation_exception) {
00696         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00697             std::endl;
00698         std::cerr << memory_allocation_exception.what() << std::endl;
00699     }
00700     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00701
00702 #ifdef MTK_PRECISION_DOUBLE
00703     gg[0] = -1.0/2.0;
00704 #else
00705     gg[0] = -1.0f/2.0f;
00706 #endif
00707     for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00708         gg[ii] = gg[ii - 1] + mtk::kOne;
00709     }
00710
00711 #if MTK_DEBUG_LEVEL > 0
00712     std::cout << "gg0 =" << std::endl;
00713     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00714         std::cout << std::setw(12) << gg[ii];
00715     }
00716     std::cout << std::endl << std::endl;
00717 #endif
00718 }

```

```

00720
00721 // Allocate 2D array to store the collection of preliminary approximations.
00722 try {
00723     prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
00724 } catch (std::bad_alloc &memory_allocation_exception) {
00725     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00726 std::endl;
00727     std::cerr << memory_allocation_exception.what() << std::endl;
00728 }
00729 memset(prem_apps_,
00730         mtk::kZero,
00731         sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00732
00733 for (auto ll = 0; ll < dim_null_; ++ll) {
00734
00735     // Re-check new generator vector for every iteration except for the first.
00736     #if MTK_DEBUG_LEVEL > 0
00737     if (ll > 0) {
00738         std::cout << "gg" << ll << " =" << std::endl;
00739         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00740             std::cout << std::setw(12) << gg[ii];
00741         }
00742         std::cout << std::endl << std::endl;
00743     }
00744     #endif
00745
00746     bool transpose{false};
00747
00748     mtk::DenseMatrix AA_(gg,
00749                           num_bndy_coeffs_, order_accuracy_ + 1,
00750                           transpose);
00751
00752     #if MTK_DEBUG_LEVEL > 0
00753     std::cout << "AA_" << ll << " =" << std::endl;
00754     std::cout << AA_ << std::endl;
00755     #endif
00756
00757     mtk::Real *ob{};
00758
00759     auto ob_ld = num_bndy_coeffs_;
00760
00761     try {
00762         ob = new mtk::Real[ob_ld];
00763     } catch (std::bad_alloc &memory_allocation_exception) {
00764         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00765         std::endl;
00766         std::cerr << memory_allocation_exception.what() << std::endl;
00767     }
00768     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00769
00770     ob[1] = mtk::kOne;
00771
00772     #if MTK_DEBUG_LEVEL > 0
00773     std::cout << "ob = " << std::endl << std::endl;
00774     for (auto ii = 0; ii < ob_ld; ++ii) {
00775         std::cout << std::setw(12) << ob[ii] << std::endl;
00776     }
00777     std::cout << std::endl;
00778     #endif
00779
00780     // However, this is an under-determined system of equations. So we can not
00781     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00782     // our LAPACKAdapter class.
00783
00784     int info_{
00785         mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
00786         ob, ob_ld)};
00787
00788     #if MTK_DEBUG_LEVEL > 0
00789     if (!info_) {
00790         std::cout << "System successfully solved!" << std::endl << std::endl;
00791     } else {
00792         std::cerr << "Error solving system! info = " << info_ << std::endl;
00793     }
00794     #endif
00795
00796     #if MTK_DEBUG_LEVEL > 0
00797

```



```

00804     std::cout << "ob =" << std::endl;
00805     for (auto ii = 0; ii < ob_ld; ++ii) {
00806         std::cout << std::setw(12) << ob[ii] << std::endl;
00807     }
00808     std::cout << std::endl;
00809     #endif
00810
00811     // This implies a DAXPY operation. However, we must construct the arguments
00812     // for this operation.
00813
00814     // Save them into the ob_bottom array:
00815
00816     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00817
00818     try {
00819         ob_bottom = new mtk::Real[dim_null_];
00820     } catch (std::bad_alloc &memory_allocation_exception) {
00821         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00822             std::endl;
00823         std::cerr << memory_allocation_exception.what() << std::endl;
00824     }
00825     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00826
00827     for (auto ii = 0; ii < dim_null_; ++ii) {
00828         ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00829     }
00830
00831     #if MTK_DEBUG_LEVEL > 0
00832     std::cout << "ob_bottom =" << std::endl;
00833     for (auto ii = 0; ii < dim_null_; ++ii) {
00834         std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00835     }
00836     std::cout << std::endl;
00837     #endif
00838
00839     // We must computed an scaled ob, sob, using the scaled null-space in
00840     // rat_basis_null_space_.
00841     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00842     // or:
00843     //      ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00844     // thus:
00845     //      Y =      a*A      *x      +      b*Y (DAXPY).
00846
00847     #if MTK_DEBUG_LEVEL > 0
00848     std::cout << "Rational basis for the null-space:" << std::endl;
00849     std::cout << rat_basis_null_space_ << std::endl;
00850     #endif
00851
00852     mtk::Real alpha{-mtk::kOne};
00853     mtk::Real beta{mtk::kOne};
00854
00855     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00856         ob_bottom, beta, ob);
00857
00858     #if MTK_DEBUG_LEVEL > 0
00859     std::cout << "scaled ob:" << std::endl;
00860     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00861         std::cout << std::setw(12) << ob[ii] << std::endl;
00862     }
00863     std::cout << std::endl;
00864     #endif
00865
00866     // We save the recently scaled solution, into an array containing these.
00867     // We can NOT start building the pi matrix, simply because I want that part
00868     // to be separated since its construction depends on the algorithm we want
00869     // to implement.
00870
00871     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00872         prem_apps_[ii*dim_null_ + 11] = ob[ii];
00873     }
00874
00875     // After the first iteration, simply shift the entries of the last
00876     // generator vector used:
00877     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00878         gg[ii]--;
00879     }
00880
00881     // Garbage collection for this loop:
00882     delete[] ob;
00883     ob = nullptr;
00884
00885

```

```

00888     delete[] ob_bottom;
00889     ob_bottom = nullptr;
00890 } // End of: for (ll = 0; ll < dim_null; ll++);
00891
00892 #if MTK_DEBUG_LEVEL > 0
00893 std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00894 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00895     for (auto jj = 0; jj < dim_null_; ++jj) {
00896         std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00897     }
00898     std::cout << std::endl;
00899 }
00900 std::cout << std::endl;
00901 #endif
00902
00903 delete[] gg;
00904 gg = nullptr;
00905
00906 return true;
00907 }
00908
00909 bool mtk::Div1D::ComputeWeights(void) {
00910
00911     // Matrix to compute the weights as in the CRSA.
00912     mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00913
00914     // Assemble the pi matrix using:
00915     // 1. The collection of scaled preliminary approximations.
00916     // 2. The collection of coefficients approximating at the interior.
00917     // 3. The scaled basis for the null-space.
00918
00919     // 1.1. Process array of scaled preliminary approximations.
00920
00921     // These are queued in scaled_solutions. Each one of these, will be a column
00922     // of the pi matrix:
00923     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00924         for (auto jj = 0; jj < dim_null_; ++jj) {
00925             pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00926                 prem_apps_[ii*dim_null_ + jj];
00927         }
00928     }
00929
00930     // 1.2. Add columns from known stencil approximating at the interior.
00931
00932     // However, these must be padded by zeros, according to their position in the
00933     // final pi matrix:
00934     auto mm = 0;
00935     for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00936         for (auto ii = 0; ii < order_accuracy_; ++ii) {
00937             pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00938                 coeffs_interior_[ii];
00939         }
00940         ++mm;
00941     }
00942
00943     rat_basis_null_space_.OrderColMajor();
00944
00945     #if MTK_DEBUG_LEVEL > 0
00946     std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00947     std::cout << rat_basis_null_space_ << std::endl;
00948     #endif
00949
00950     // 1.3. Add final set of columns: rational basis for null-space.
00951     for (auto jj = dim_null_ + (order_accuracy_/2 + 1); jj < num_bndy_coeffs_ - 1; ++jj) {
00952         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00953             auto og =
00954                 (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00955             auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00956             pi.data()[de] = rat_basis_null_space_.data()[og];
00957         }
00958     }
00959
00960     #if MTK_DEBUG_LEVEL > 0
00961     std::cout << "coeffs_interior_ =" << std::endl;
00962     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00963         std::cout << std::setw(12) << coeffs_interior_[ii];
00964     }
00965     std::cout << std::endl << std::endl;
00966     #endif
00967 }
00968
00969

```

```

00970  #if MTK_DEBUG_LEVEL >0
00971  std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00972  std::cout << pi << std::endl;
00973  #endif
00974
00975
00976
00977  // This imposes the mimetic condition.
00978
00979  mtk::Real *hh{}; // Right-hand side to compute weights in the C{R,B}SA.
00980
00981  try {
00982      hh = new mtk::Real[num_bndy_coeffs_];
00983  } catch (std::bad_alloc &memory_allocation_exception) {
00984      std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00985          std::endl;
00986      std::cerr << memory_allocation_exception.what() << std::endl;
00987  }
00988  memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00989
00990  hh[0] = -mtk::kOne;
00991  for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00992      auto aux_xx = mtk::kZero;
00993      for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00994          aux_xx += coeffs_interior_[jj];
00995      }
00996      hh[ii] = -mtk::kOne*aux_xx;
00997  }
00998
00999
01000
01001  // That is, we construct a system, to solve for the weights.
01002
01003  // Once again we face the challenge of solving with LAPACK. However, for the
01004  // CRSA, this matrix PI is over-determined, since it has more rows than
01005  // unknowns. However, according to the theory, the solution to this system is
01006  // unique. We will use dgels_.
01007
01008  try {
01009      weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01010  } catch (std::bad_alloc &memory_allocation_exception) {
01011      std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01012          std::endl;
01013      std::cerr << memory_allocation_exception.what() << std::endl;
01014  }
01015  memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01016
01017  int weights_ld{pi.num_cols() + 1};
01018
01019  // Preserve hh.
01020  std::copy(hh, hh + weights_ld, weights_cbs_);
01021
01022  pi.Transpose();
01023
01024  int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
01025      pi, weights_cbs_, weights_ld)};
01026
01027  #if MTK_DEBUG_LEVEL > 0
01028  if (!info) {
01029      std::cout << "System successfully solved!" << std::endl << std::endl;
01030  } else {
01031      std::cerr << "Error solving system! info = " << info << std::endl;
01032  }
01033  #endif
01034
01035  #if MTK_DEBUG_LEVEL > 0
01036  std::cout << "hh =" << std::endl;
01037  for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01038      std::cout << std::setw(11) << hh[ii] << std::endl;
01039  }
01040  std::cout << std::endl;
01041  #endif
01042
01043  // Preserve the original weights for research.
01044
01045  try {
01046      weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01047  } catch (std::bad_alloc &memory_allocation_exception) {
01048      std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01049          std::endl;
01050      std::cerr << memory_allocation_exception.what() << std::endl;
01051  }
01052  memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);

```

```

01052
01053     std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01054
01055     #if MTK_DEBUG_LEVEL > 0
01056     std::cout << "weights_CRSA + lambda =" << std::endl;
01057     for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01058         std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01059     }
01060     std::cout << std::endl;
01061     #endif
01062
01063
01064
01065     if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01066         int minrow_{std::numeric_limits<int>::infinity()};
01067
01068         mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
01069 order_accuracy_)};
01070         mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01071
01072
01073
01074         mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01075
01076         for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01077             for (auto jj = 0; jj < dim_null_; ++jj) {
01078                 phi.data()[ii*(order_accuracy_ + 1) + jj] = prem_apps_[ii*dim_null_ + jj];
01079             }
01080         }
01081
01082         int aux{}; // Auxiliary variable.
01083         for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01084             for (auto ii = 0; ii < order_accuracy_; ++ii) {
01085                 phi.data()[ii + aux]*order_accuracy_ + jj] = coeffs_interior[ii];
01086             }
01087             ++aux;
01088         }
01089
01090         for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01091             for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01092                 phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01093             }
01094         }
01095
01096         for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01097             for (auto ii = 0; ii < dim_null_; ++ii) {
01098                 phi.data()[ii + order_accuracy_ - dim_null_ + jj*order_accuracy_] =
01099                     -pre_apps_[(dim_null_ - ii - 1 + jj*dim_null_)];
01100             }
01101         }
01102
01103         for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
01104             for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01105                 auto swap = phi.data()[ii*order_accuracy_+jj];
01106                 phi.data()[ii*order_accuracy_ + jj] =
01107                     phi.data()[ii*order_accuracy_+jj];
01108                 phi.data()[ii*order_accuracy_+jj] = swap;
01109             }
01110         }
01111
01112         #if MTK_DEBUG_LEVEL > 0
01113         std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01114         std::cout << phi << std::endl;
01115         #endif
01116
01117
01118
01119         mtk::Real *lamed{}; // Used to build big lambda.
01120
01121         try {
01122             lamed = new mtk::Real[dim_null_];
01123         } catch (std::bad_alloc &memory_allocation_exception) {
01124             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01125                 std::endl;
01126             std::cerr << memory_allocation_exception.what() << std::endl;
01127         }
01128         memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01129
01130         for (auto ii = 0; ii < dim_null_; ++ii) {
01131             lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01132         }
01133
01134         #if MTK_DEBUG_LEVEL > 0

```

```

01135     std::cout << "lamed =" << std::endl;
01136     for (auto ii = 0; ii < dim_null_; ++ii) {
01137         std::cout << std::setw(12) << lamed[ii] << std::endl;
01138     }
01139     std::cout << std::endl;
01140     #endif
01141
01142     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01143         mtk::Real temp = mtk::kZero;
01144         for (auto jj = 0; jj < dim_null_; ++jj) {
01145             temp = temp +
01146                 lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01147         }
01148         hh[ii] = hh[ii] - temp;
01149     }
01150
01151     #if MTK_DEBUG_LEVEL > 0
01152     std::cout << "big_lambda =" << std::endl;
01153     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01154         std::cout << std::setw(12) << hh[ii] << std::endl;
01155     }
01156     std::cout << std::endl;
01157     #endif
01158
01159     int copy_result{};
01160
01161     mtk::Real normerr_; // Norm of the error for the solution on each row.
01162
01163     for (auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01164         normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01165 data(),
01166                                     order_accuracy_ + 1,
01167                                     order_accuracy_,
01168                                     order_accuracy_,
01169                                     hh,
01170                                     weights_cbs_,
01171                                     row_,
01172                                     mimetic_threshold_,
01173                                     copy_result);
01174
01175         mtk::Real aux{normerr_/norm_};
01176
01177         #if MTK_DEBUG_LEVEL>0
01178         std::cout << "Relative norm: " << aux << " " << std::endl;
01179         std::cout << std::endl;
01180         #endif
01181
01182         if (aux < minnorm_) {
01183             minnorm_ = aux;
01184             minrow_ = row_;
01185         }
01186     }
01187
01188     #if MTK_DEBUG_LEVEL > 0
01189     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01190         std::endl;
01191     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01192         std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01193     }
01194     std::cout << std::endl;
01195     #endif
01196
01197
01198
01199     // After we know which row yields the smallest relative norm that row is
01200     // chosen to be the objective function and the result of the optimizer is
01201     // chosen to be the new weights_.
01202
01203     #if MTK_DEBUG_LEVEL > 0
01204     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01205         minrow_ + 1 << std::endl;
01206     std::cout << std::endl;
01207     #endif
01208
01209     copy_result = 1;
01210     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01211 data(),
01212                                     order_accuracy_ + 1,
01213                                     order_accuracy_,
01214                                     order_accuracy_,
01215                                     hh,
01216                                     weights_cbs_,

```

```

01216                                     minrow_,
01217                                     mimetic_threshold_,
01218                                     copy_result);
01219     mtk::Real aux_{normerr_/norm_};
01220     #if MTK_DEBUG_LEVEL > 0
01221     std::cout << "Relative norm: " << aux_ << std::endl;
01222     std::cout << std::endl;
01223     #endif
01224
01225     delete [] lamed;
01226     lamed = nullptr;
01227 }
01228
01229 delete [] hh;
01230 hh = nullptr;
01231
01232 return true;
01233 }
01234
01235 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01236
01237     #if MTK_DEBUG_LEVEL > 0
01238     std::cout << "weights_CBSA + lambda =" << std::endl;
01239     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01240         std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01241     }
01242     std::cout << std::endl;
01243     #endif
01244
01245     mtk::Real *lambda{}; // Collection of bottom values from weights_.
01246
01247     try {
01248         lambda = new mtk::Real[dim_null_];
01249     } catch (std::bad_alloc &memory_allocation_exception) {
01250         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01251             std::endl;
01252         std::cerr << memory_allocation_exception.what() << std::endl;
01253     }
01254     memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01255
01256     for (auto ii = 0; ii < dim_null_; ++ii) {
01257         lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01258     }
01259
01260     #if MTK_DEBUG_LEVEL > 0
01261     std::cout << "lambda =" << std::endl;
01262     for (auto ii = 0; ii < dim_null_; ++ii) {
01263         std::cout << std::setw(12) << lambda[ii] << std::endl;
01264     }
01265     std::cout << std::endl;
01266     #endif
01267
01268     mtk::Real *alpha{}; // Collection of alpha values.
01269
01270     try {
01271         alpha = new mtk::Real[dim_null_];
01272     } catch (std::bad_alloc &memory_allocation_exception) {
01273         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01274             std::endl;
01275         std::cerr << memory_allocation_exception.what() << std::endl;
01276     }
01277     memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01278
01279     for (auto ii = 0; ii < dim_null_; ++ii) {
01280         alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01281     }
01282
01283     #if MTK_DEBUG_LEVEL > 0
01284     std::cout << "alpha =" << std::endl;
01285     for (auto ii = 0; ii < dim_null_; ++ii) {
01286         std::cout << std::setw(12) << alpha[ii] << std::endl;
01287     }
01288     std::cout << std::endl;
01289     #endif
01290
01291     try {
01292         mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01293     } catch (std::bad_alloc &memory_allocation_exception) {

```

```

01300     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01301     std::endl;
01302     std::cerr << memory_allocation_exception.what() << std::endl;
01303 }
01304 memset(mim_bndy_, mtk::kZero, sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01305
01306 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01307     for (auto jj = 0; jj < dim_null_; ++jj) {
01308         mim_bndy_[ii*dim_null_ + jj] =
01309             prem_apps_[ii*dim_null_ + jj] +
01310             alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01311     }
01312 }
01313
01314 #if MTK_DEBUG_LEVEL > 0
01315 std::cout << "Collection of mimetic approximations:" << std::endl;
01316 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01317     for (auto jj = 0; jj < dim_null_; ++jj) {
01318         std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01319     }
01320     std::cout << std::endl;
01321 }
01322 std::cout << std::endl;
01323 #endif
01324 delete[] lambda;
01325 lambda = nullptr;
01326 delete[] alpha;
01327 alpha = nullptr;
01328 return true;
01329 }
01330
01331 bool mtk::Div1D::AssembleOperator(void) {
01332 // The output array will have this form:
01333 // 1. The first entry of the array will contain the used order order_accuracy_.
01334 // 2. The second entry of the array will contain the collection of
01335 // approximating coefficients for the interior of the grid.
01336 // 3. IF order_accuracy_ > 2, then the third entry will contain a collection of weights.
01337 // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the collections of
01338 // approximating coefficients for the west boundary of the grid.
01339 if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01340     divergence_length_ =
01341         1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
01342 } else {
01343     divergence_length_ = 1 + order_accuracy_;
01344 }
01345
01346 #if MTK_DEBUG_LEVEL > 0
01347 std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01348 #endif
01349 try {
01350     divergence_ = new double[divergence_length_];
01351 } catch (std::bad_alloc &memory_allocation_exception) {
01352     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01353     std::endl;
01354     std::cerr << memory_allocation_exception.what() << std::endl;
01355 }
01356 memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01357
01358 divergence_[0] = order_accuracy_;
01359
01360 for (auto ii = 0; ii < order_accuracy_; ++ii) {
01361     divergence_[ii + 1] = coeffs_interior_[ii];
01362 }
01363
01364 if (order_accuracy_ > 2) {
01365     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01366         divergence_[1 + order_accuracy_ + ii] = weights_cbs_[ii];
01367     }
01368 }
01369
01370 if (order_accuracy_ > 2) {

```

```

01386     auto offset = (2*order_accuracy_ + 1);
01387     int mm{};
01388     for (auto ii = 0; ii < dim_null_; ++ii) {
01389         for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01390             divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01391             ++mm;
01392         }
01393     }
01394 }
01395
01396 #if MTK_DEBUG_LEVEL > 0
01397 std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01398 std::cout << std::endl;
01399 #endif
01400
01401 return true;
01402 }

```

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

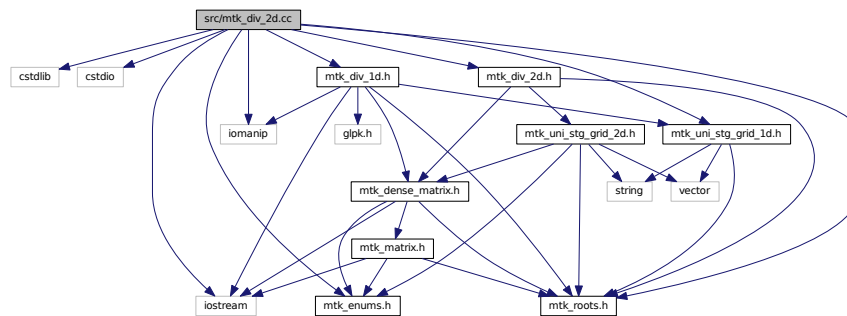
Implements the class Div2D.

```

#include <cstdlib>
#include <stdio>
#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:



### 17.63.1 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](#).



## 17.64 mtk\_div\_2d.cc

```

00001
00011 /*
00012 Copyright (C) 2015, Computational Science Research Center, San Diego State
00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
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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 if (!info) {
00096     std::cerr << "Mimetic div could not be built." << std::endl;
00097     return info;
00098 }
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 dx(div.ReturnAsDenseMatrix(grid_x));
00109 mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00110
00111 bool padded{true};
00112 bool transpose{false};
00113
00114 mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00115 mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00116
00117 mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00118 mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00119
00120 #if MTK_DEBUG_LEVEL > 0
00121 std::cout << "Dx: " << mx << " by " << nx << std::endl;
00122 std::cout << "Iy : " << num_cells_y << " by " << ny << std::endl;
00123 std::cout << "Dy: " << my << " by " << ny << std::endl;
00124 std::cout << "Ix : " << num_cells_x << " by " << nx << std::endl;
00125 std::cout << "Div 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00126     nx*ny << std::endl;
00127 #endif
00128
00129 mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00130
00131 for (auto ii = 0; ii < mx*my; ii++) {
00132     for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00133         d2d.SetValue(ii, jj, dxy.GetValue(ii, jj));
00134     }
00135     for (auto kk=0; kk<ny*num_cells_x; kk++) {
00136         d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00137     }
00138 }
00139
00140 divergence_ = d2d;
00141
00142 return info;
00143 }
00144
00145 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix() const {
00146
00147     return divergence_;
00148 }

```

## 17.65 src/mtk\_glpk\_adapter.cc File Reference

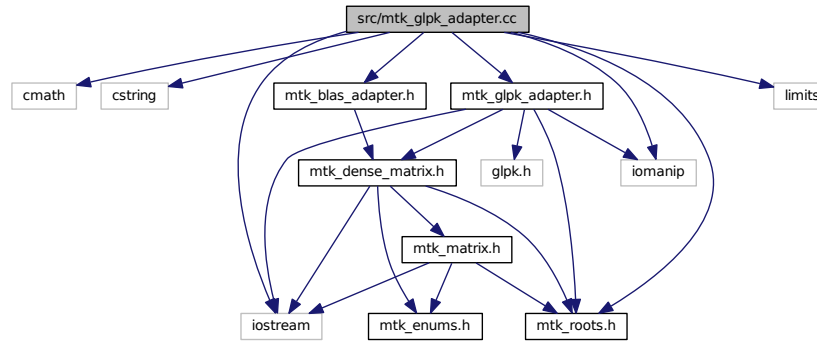
Adapter class for the GLPK API.

```

#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:



### 17.65.1 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](#).

## 17.66 mtk\_glpk\_adapter.cc

```

00001
00019 /*
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00021 University. All rights reserved.
00022
00023 Redistribution and use in source and binary forms, with or without modification,
00024 are permitted provided that the following conditions are met:
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,
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #include <cmath>
00066 #include <cstring>
00067
00068 #include <iostream>
00069 #include <iomanip>
00070 #include <limits>
00071
00072 #include "mtk_roots.h"
00073 #include "mtk_blas_adapter.h"
00074 #include "mtk_glpk_adapter.h"
00075
00076 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
    mtk::Real *A,
00077
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.
00101     int matsize;      // Size of the matrix.
00102     int glp_index{1}; // Index of the objective function.
00103     int ii;           // Iterator.
00104     int jj;           // Iterator.
00105
00106     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     problem_size = lp_nrows*lp_ncols + 1;
00123
00124     try {
00125         ia = new int[problem_size];
00126     } catch (std::bad_alloc &memory_allocation_exception) {
00127         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00128             std::endl;
00129         std::cerr << memory_allocation_exception.what() << std::endl;
00130     }
00131     memset(ia, 0, sizeof(ia[0])*problem_size);
00132
00133     try {
00134         ja = new int[problem_size];
00135     } catch (std::bad_alloc &memory_allocation_exception) {
00136         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00137             std::endl;
00138         std::cerr << memory_allocation_exception.what() << std::endl;
00139     }
00140     memset(ja, 0, sizeof(ja[0])*problem_size);
00141
00142     try {
00143         ar = new mtk::Real[problem_size];
00144     } catch (std::bad_alloc &memory_allocation_exception) {
00145         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00146             std::endl;
00147         std::cerr << memory_allocation_exception.what() << std::endl;
00148     }
00149     memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00150
00151     try {
00152         objective = new mtk::Real[lp_ncols + 1];
00153     } catch (std::bad_alloc &memory_allocation_exception) {
00154         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00155             std::endl;
00156         std::cerr << memory_allocation_exception.what() << std::endl;
00157     }
00158     memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00159
00160     try {
00161         rhs = new mtk::Real[lp_nrows + 1];
00162     } catch (std::bad_alloc &memory_allocation_exception) {
00163         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00164             std::endl;
00165         std::cerr << memory_allocation_exception.what() << std::endl;
00166     }
00167     memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00168
00169     try {
00170         err = new mtk::Real[lp_nrows];
00171     } catch (std::bad_alloc &memory_allocation_exception) {
00172         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00173             std::endl;
00174         std::cerr << memory_allocation_exception.what() << std::endl;
00175     }
00176     memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00177
00178     #if MTK_DEBUG_LEVEL > 0
00179     std::cout << "Problem size: " << problem_size << std::endl;
00180     std::cout << "lp_nrows = " << lp_nrows << std::endl;
00181     std::cout << "lp_ncols = " << lp_ncols << std::endl;
00182     #endif
00183     lp = glp_create_prob();
00184

```

```

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) {
00257           glp_index++;
00258       }
00259       ia[ii] = glp_index;
00260       ja[ii] = (ii - 1) % lp_ncols + 1;
00261   }
00262
00263
00264
00265
00266
00267
00268
00269
00270
00271
00272
00273
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
00329 }
00330

```

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

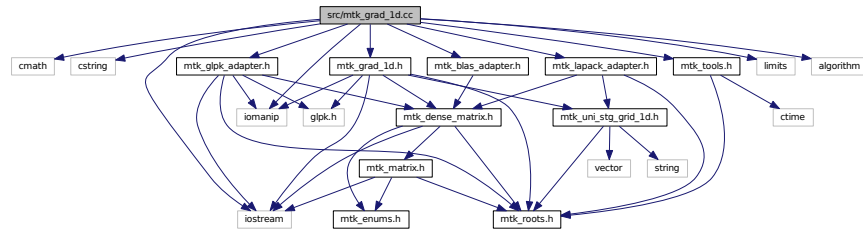
Implements the class Grad1D.

```

#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)`

### 17.67.1 Detailed Description

This class implements a 1D gradient 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 `mtk::BLASAdapter`.

Definition in file `mtk_grad_1d.cc`.

## 17.68 mtk\_grad\_1d.cc

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
```



```

00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00034
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00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
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00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
00075 #include "mtk_grad_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Grad1D &in) {
00080
00081     stream << "gradient_[0] = " << std::setw(9) << in.gradient_[0] << std::endl;
00082
00083     stream << "gradient_[1:" << in.order_accuracy_ << "] = ";
00084     for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00085         stream << std::setw(9) << in.gradient_[ii] << " ";
00086     }
00087     stream << std::endl;
00088
00089     stream << "gradient_[\" << in.order_accuracy_ + 1 << ":" <<
00090         2*in.order_accuracy_ << "] = ";
00091     for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
00092 order_accuracy_; ++ii) {
00093         stream << std::setw(9) << in.gradient_[ii] << " ";
00094     }
00095     stream << std::endl;
00096
00097     int offset{2*in.order_accuracy_ + 1};
00098     int mm {};
00099
00100     stream << "gradient_[\" << offset + mm << ":" <<
00101         offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00102
00103     if (in.order_accuracy_ > mtk::kDefaultOrderAccuracy) {
00104         for (auto ii = 0; ii < in.num_bndy_approxs_ ; ++ii) {
00105             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,
00183     Real mimetic_threshold) {
00184
00185     #if MTK_DEBUG_LEVEL > 0
00186     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00187     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00188     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00189         __FILE__, __LINE__, __func__);
00190
00191     if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00192         std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00193     }

```

```

00193
00194     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00195     std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00196     #endif
00197
00198     order_accuracy_ = order_accuracy;
00199     mimetic_threshold_ = mimetic_threshold;
00200
00202
00203     bool abort_construction = ComputeStencilInteriorGrid();
00204
00205     #if MTK_DEBUG_LEVEL > 0
00206     if (!abort_construction) {
00207         std::cerr << "Could NOT complete stage 1." << std::endl;
00208         std::cerr << "Exiting..." << std::endl;
00209         return false;
00210     }
00211     #endif
00212
00213     // At this point, we already have the values for the interior stencil stored
00214     // in the coeffs_interior_ array.
00215
00216     dim_null_ = order_accuracy_/2 - 1;
00217
00218     num_bndy_approxs_ = dim_null_ + 1;
00219
00220     #ifdef MTK_PRECISION_DOUBLE
00221     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00222     #else
00223     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00224     #endif
00225
00227
00228     // For this we will follow recommendations given in:
00229     //
00230     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00231     //
00232     // We will compute the QR Factorization of the transpose, as in the
00233     // following (MATLAB) pseudo-code:
00234     //
00235     // [Q,R] = qr(V'); % Full QR as defined in
00236     // % http://www.stanford.edu/class/ee263/notes/qr\_matlab.pdf
00237     //
00238     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00239     //
00240     // However, given the nature of the Vandermonde matrices we've just
00241     // computed, they all posses the same null-space. Therefore, we impose the
00242     // convention of computing the null-space of the first Vandermonde matrix
00243     // (west boundary).
00244
00245     // In the case of the gradient, the first Vandermonde system has a unique
00246     // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00247     // matrix used to assemble said system, will have an empty null-space.
00248
00249     // Therefore, we only compute a rational basis for the case of order higher
00250     // than second.
00251
00252     if (dim_null_ > 0) {
00253
00254         abort_construction = ComputeRationalBasisNullSpace();
00255
00256         #if MTK_DEBUG_LEVEL > 0
00257         if (!abort_construction) {
00258             std::cerr << "Could NOT complete stage 2.1." << std::endl;
00259             std::cerr << "Exiting..." << std::endl;
00260             return false;
00261         }
00262         #endif
00263     }
00264
00266
00267     abort_construction = ComputePreliminaryApproximations();
00268
00269     #if MTK_DEBUG_LEVEL > 0
00270     if (!abort_construction) {
00271         std::cerr << "Could NOT complete stage 2.2." << std::endl;
00272         std::cerr << "Exiting..." << std::endl;
00273         return false;
00274     }
00275     #endif
00276

```

```

00278
00279 abort_construction = ComputeWeights();
00280
00281 #if MTK_DEBUG_LEVEL > 0
00282 if (!abort_construction) {
00283     std::cerr << "Could NOT complete stage 2.3." << std::endl;
00284     std::cerr << "Exiting..." << std::endl;
00285     return false;
00286 }
00287 #endif
00288
00290
00291 if (dim_null_ > 0) {
00292
00293     abort_construction = ComputeStencilBoundaryGrid();
00294
00295     #if MTK_DEBUG_LEVEL > 0
00296     if (!abort_construction) {
00297         std::cerr << "Could NOT complete stage 2.4." << std::endl;
00298         std::cerr << "Exiting..." << std::endl;
00299         return false;
00300     }
00301     #endif
00302 }
00303
00305
00306 // Once we have the following three collections of data:
00307 // (a) the coefficients for the interior,
00308 // (b) the coefficients for the boundary (if it applies),
00309 // (c) and the weights (if it applies),
00310 // we will store everything in the output array:
00311
00312 abort_construction = AssembleOperator();
00313
00314 #if MTK_DEBUG_LEVEL > 0
00315 if (!abort_construction) {
00316     std::cerr << "Could NOT complete stage 3." << std::endl;
00317     std::cerr << "Exiting..." << std::endl;
00318     return false;
00319 }
00320 #endif
00321
00322 return true;
00323 }
00324
00325 int mtk::Grad1D::num_bndy_coeffs() const {
00326     return num_bndy_coeffs_;
00327 }
00328
00329
00330 mtk::Real *mtk::Grad1D::coeffs_interior() const {
00331
00332     return coeffs_interior_;
00333 }
00334
00335 mtk::Real *mtk::Grad1D::weights_crs() const {
00336
00337     return weights_crs_;
00338 }
00339
00340 mtk::Real *mtk::Grad1D::weights_cbs() const {
00341
00342     return weights_cbs_;
00343 }
00344
00345 mtk::DenseMatrix mtk::Grad1D::mim_bndy() const {
00346
00347     mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00348
00349     auto counter = 0;
00350     for (auto ii = 0; ii < dim_null_; ++ii) {
00351         for (auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00352             xx.SetValue(ii,jj, gradient_[2*order_accuracy_ + 1 + counter]);
00353             counter++;
00354         }
00355     }
00356
00357     return xx;
00358 }
00359
00360 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(

```

```

00361     mtk::Real west,
00362                                     mtk::Real east,
00363                                     int num_cells_x) const {
00364     int nn{num_cells_x}; // Number of cells on the grid.
00365
00366     #if MTK_DEBUG_LEVEL > 0
00367     mtk::Tools::Prevent(east < west, __FILE__, __LINE__, __func__);
00368     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00369     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00370     #endif
00371
00372     mtk::Real delta_x = (east - west)/((mtk::Real) num_cells_x);
00373
00374     mtk::Real inv_delta_x{mtk::kOne/delta_x};
00375
00376     int gg_num_rows = nn + 1;
00377     int gg_num_cols = nn + 2;
00378     int elements_per_row = num_bndy_coeffs_;
00379     int num_extra_rows = order_accuracy_/2;
00380
00381     // Output matrix featuring sizes for gradient operators.
00382     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00383
00384     auto ee_index = 0;
00385     for (auto ii = 0; ii < num_extra_rows; ii++) {
00386         auto cc = 0;
00387         for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00388             if(cc >= elements_per_row) {
00389                 out.SetValue(ii, jj, mtk::kZero);
00390             } else {
00391                 out.SetValue(ii, jj,
00392                             gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00393                 cc++;
00394             }
00395         }
00396     }
00397 }
00398
00399
00401
00402     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00403         auto jj = ii - num_extra_rows + 1;
00404         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00405             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00406         }
00407     }
00408
00409
00410
00411     ee_index = 0;
00412     for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00413         auto cc = 0;
00414         for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00415             if(cc >= elements_per_row) {
00416                 out.SetValue(ii, jj, mtk::kZero);
00417             } else {
00418                 out.SetValue(ii, jj,
00419                             -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00420                 cc++;
00421             }
00422         }
00423     }
00424
00425     return out;
00426 }
00427
00428 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
00429     const UniStgGrid1D &grid) const {
00430
00431     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00432
00433     #if MTK_DEBUG_LEVEL > 0
00434     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00435     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00436     #endif
00437
00438     mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00439
00440     int gg_num_rows = nn + 1;
00441     int gg_num_cols = nn + 2;
00442     int elements_per_row = num_bndy_coeffs_;
00443     int num_extra_rows = order_accuracy_/2;

```

```

00444
00445 // Output matrix featuring sizes for gradient operators.
00446 mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00447
00448
00449
00450 auto ee_index = 0;
00451 for (auto ii = 0; ii < num_extra_rows; ii++) {
00452     auto cc = 0;
00453     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00454         if(cc >= elements_per_row) {
00455             out.SetValue(ii, jj, mtk::kZero);
00456         } else {
00457             out.SetValue(ii, jj,
00458                 gradient_[2*order_accuracy_ + 1 + ee_index++] * inv_delta_x);
00459             cc++;
00460         }
00461     }
00462 }
00463
00464
00465
00466 for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00467     auto jj = ii - num_extra_rows + 1;
00468     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00469         out.SetValue(ii, jj, coeffs_interior_[cc] * inv_delta_x);
00470     }
00471 }
00472
00473
00474
00475 ee_index = 0;
00476 for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00477     auto cc = 0;
00478     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00479         if(cc >= elements_per_row) {
00480             out.SetValue(ii, jj, mtk::kZero);
00481         } else {
00482             out.SetValue(ii, jj,
00483                 -gradient_[2*order_accuracy_ + 1 + ee_index++] * inv_delta_x);
00484             cc++;
00485         }
00486     }
00487 }
00488
00489 return out;
00490 }
00491
00492 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix
00493 (
00494     int num_cells_x) const {
00495
00496     int nn{num_cells_x}; // Number of cells on the grid.
00497
00498     #if MTK_DEBUG_LEVEL > 0
00499     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00500     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00501     #endif
00502
00503     int gg_num_rows = nn + 1;
00504     int gg_num_cols = nn + 2;
00505     int elements_per_row = num_bndy_coeffs_;
00506     int num_extra_rows = order_accuracy_/2;
00507
00508     // Output matrix featuring sizes for gradient operators.
00509     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00510
00511
00512
00513 auto ee_index = 0;
00514 for (auto ii = 0; ii < num_extra_rows; ii++) {
00515     auto cc = 0;
00516     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00517         if(cc >= elements_per_row) {
00518             out.SetValue(ii, jj, mtk::kZero);
00519         } else {
00520             out.SetValue(ii, jj,
00521                 gradient_[2*order_accuracy_ + 1 + ee_index++]);
00522             cc++;
00523         }
00524     }
00525 }
00526
00527
00528 for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {

```

```

00529     auto jj = ii - num_extra_rows + 1;
00530     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00531         out.SetValue(ii, jj, coeffs_interior_[cc]);
00532     }
00533 }
00534
00536
00537 ee_index = 0;
00538 for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00539     auto cc = 0;
00540     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00541         if (cc >= elements_per_row) {
00542             out.SetValue(ii, jj, mtk::kZero);
00543         } else {
00544             out.SetValue(ii, jj,
00545                 -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00546             cc++;
00547         }
00548     }
00549 }
00550
00551 return out;
00552 }
00553
00554 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00555
00557     mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00559
00560     try {
00561         pp = new mtk::Real[order_accuracy_];
00562     } catch (std::bad_alloc &memory_allocation_exception) {
00563         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00564             std::endl;
00565         std::cerr << memory_allocation_exception.what() << std::endl;
00566     }
00567     memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00568
00569     #ifdef MTK_PRECISION_DOUBLE
00570     pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00571     #else
00572     pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00573     #endif
00574
00575     for (auto ii = 1; ii < order_accuracy_; ++ii) {
00576         pp[ii] = pp[ii - 1] + mtk::kOne;
00577     }
00578
00579     #if MTK_DEBUG_LEVEL > 0
00580     std::cout << "pp =" << std::endl;
00581     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00582         std::cout << std::setw(12) << pp[ii];
00583     }
00584     std::cout << std::endl << std::endl;
00585     #endif
00586
00588
00589     bool transpose{false};
00590
00591     mtk::DenseMatrix vander_matrix(pp, order_accuracy_, order_accuracy_, transpose);
00592
00593     #if MTK_DEBUG_LEVEL > 0
00594     std::cout << "vander_matrix =" << std::endl;
00595     std::cout << vander_matrix << std::endl << std::endl;
00596     #endif
00597
00599
00600     try {
00601         coeffs_interior_ = new mtk::Real[order_accuracy_];
00602     } catch (std::bad_alloc &memory_allocation_exception) {
00603         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00604             std::endl;
00605         std::cerr << memory_allocation_exception.what() << std::endl;
00606     }
00607     memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00608
00609     coeffs_interior_[1] = mtk::kOne;
00610
00611     #if MTK_DEBUG_LEVEL > 0
00612     std::cout << "oo =" << std::endl;
00613     for (auto ii = 0; ii < order_accuracy_; ++ii) {

```

```

00614     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00615 }
00616 std::cout << std::endl;
00617 #endif
00618
00620
00621 int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00622                                               coeffs_interior_)};
00623
00624 #if MTK_DEBUG_LEVEL > 0
00625 if (!info) {
00626     std::cout << "System solved! Interior stencil attained!" << std::endl;
00627     std::cout << std::endl;
00628 }
00629 else {
00630     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00631     std::cerr << "Exiting..." << std::endl;
00632     return false;
00633 }
00634 #endif
00635
00636 #if MTK_DEBUG_LEVEL > 0
00637 std::cout << "coeffs_interior_ =" << std::endl;
00638 for (auto ii = 0; ii < order_accuracy_; ++ii) {
00639     std::cout << std::setw(12) << coeffs_interior_[ii];
00640 }
00641 std::cout << std::endl << std::endl;
00642 #endif
00643
00644 delete [] pp;
00645 pp = nullptr;
00646
00647 return true;
00648 }
00649
00650 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00651
00653
00654     mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00655
00656     try {
00657         gg = new mtk::Real[num_bndy_coeffs_];
00658     } catch (std::bad_alloc &memory_allocation_exception) {
00659         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00660             std::endl;
00661         std::cerr << memory_allocation_exception.what() << std::endl;
00662     }
00663     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00664
00665     #ifdef MTK_PRECISION_DOUBLE
00666     gg[1] = 1.0/2.0;
00667     #else
00668     gg[1] = 1.0f/2.0f;
00669     #endif
00670     for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00671         gg[ii] = gg[ii - 1] + mtk::kOne;
00672     }
00673
00674     #if MTK_DEBUG_LEVEL > 0
00675     std::cout << "gg =" << std::endl;
00676     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00677         std::cout << std::setw(12) << gg[ii];
00678     }
00679     std::cout << std::endl << std::endl;
00680     #endif
00681
00682
00683
00684     bool tran{true}; // Should I transpose the Vandermonde matrix.
00685
00686     mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00687
00688     #if MTK_DEBUG_LEVEL > 0
00689     std::cout << "aa_west_t =" << std::endl;
00690     std::cout << aa_west_t << std::endl;
00691     #endif
00692
00693
00694
00695     mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
00696         (aa_west_t));
00697
00698     #if MTK_DEBUG_LEVEL > 0

```



```

00698     std::cout << "qq_t = " << std::endl;
00699     std::cout << qq_t << std::endl;
00700     #endif
00701
00702
00703
00704     int kk_num_rows{num_bndy_coeffs_};
00705     int kk_num_cols{dim_null_};
00706
00707     mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00708
00709     // In the case of the gradient, even though we must solve for a null-space
00710     // of dimension 2, we must only extract ONE basis for the kernel.
00711     // We perform this extraction here:
00712
00713     int aux_{kk_num_rows - kk_num_cols};
00714     for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00715         aux_--;
00716         for (auto jj = 0; jj < kk_num_rows; jj++) {
00717             kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00718                 qq_t.data()[ii*num_bndy_coeffs_ + jj];
00719         }
00720     }
00721
00722     #if MTK_DEBUG_LEVEL > 0
00723     std::cout << "kk =" << std::endl;
00724     std::cout << kk << std::endl;
00725     std::cout << "kk.num_rows() = " << kk.num_rows() << std::endl;
00726     std::cout << "kk.num_cols() = " << kk.num_cols() << std::endl;
00727     std::cout << std::endl;
00728     #endif
00729
00730
00731
00732     // Scale thus requesting that the last entries of the attained basis for the
00733     // null-space, adopt the pattern we require.
00734     // Essentially we will implement the following MATLAB pseudo-code:
00735     // scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00736     // SK = kk*scalers
00737     // where SK is the scaled null-space.
00738
00739     // In this point, we almost have all the data we need correctly allocated
00740     // in memory. We will create the matrix iden_, and elements we wish to scale in
00741     // the kk array. Using the concept of the leading dimension, we could just
00742     // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00743     // GET how does it work. So I will just create a matrix with the content of
00744     // this array that we need, solve for the scalers and then scale the
00745     // whole kk:
00746
00747     // We will then create memory for that sub-matrix of kk (subk).
00748
00749     mtk::DenseMatrix subk(dim_null_, dim_null_);
00750
00751     auto zz = 0;
00752     for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00753         for (auto jj = 0; jj < dim_null_; jj++) {
00754             subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00755         }
00756         zz++;
00757     }
00758
00759     #if MTK_DEBUG_LEVEL > 0
00760     std::cout << "subk =" << std::endl;
00761     std::cout << subk << std::endl;
00762     #endif
00763
00764     subk.Transpose();
00765
00766     #if MTK_DEBUG_LEVEL > 0
00767     std::cout << "subk_t =" << std::endl;
00768     std::cout << subk << std::endl;
00769     #endif
00770
00771     bool padded{false};
00772     tran = false;
00773
00774     mtk::DenseMatrix iden(dim_null_, padded, tran);
00775
00776     #if MTK_DEBUG_LEVEL > 0
00777     std::cout << "iden =" << std::endl;
00778     std::cout << iden << std::endl;
00779     #endif
00780

```

```

00781 // Solve the system to compute the scalars.
00782 // An example of the system to solve, for k = 8, is:
00783 //
00784 // subk*scalars = iden or
00785 //
00786 // | 0.386018 -0.0339244 -0.129478 | | 1 0 0 |
00787 // | -0.119774 0.0199423 0.0558632 |*scalars = | 0 1 0 |
00788 // | 0.0155708 -0.00349546 -0.00853182 | | 0 0 1 |
00789 //
00790 // Notice this is a nrhs = 3 system.
00791 // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalars... they
00792 // will be stored in the created identity matrix.
00793 // Let us first transpose subk (because of LAPACK):
00794
00795 int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00796
00797 #if MTK_DEBUG_LEVEL > 0
00798 if (!info) {
00799     std::cout << "System successfully solved!" <<
00800     std::endl;
00801 } else {
00802     std::cerr << "Something went wrong solving system! info = " << info <<
00803     std::endl;
00804     std::cerr << "Exiting..." << std::endl;
00805     return false;
00806 }
00807 std::cout << std::endl;
00808 #endif
00809
00810 #if MTK_DEBUG_LEVEL > 0
00811 std::cout << "Computed scalars:" << std::endl;
00812 std::cout << iden << std::endl;
00813 #endif
00814
00815 // Multiply the two matrices to attain a scaled basis for null-space.
00816
00817 rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00818
00819 #if MTK_DEBUG_LEVEL > 0
00820 std::cout << "Rational basis for the null-space:" << std::endl;
00821 std::cout << rat_basis_null_space_ << std::endl;
00822 #endif
00823
00824 // At this point, we have a rational basis for the null-space, with the
00825 // pattern we need! :)
00826
00827 delete [] gg;
00828 gg = nullptr;
00829
00830 return true;
00831 }
00832
00833 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00834
00835     mtk::Real *gg{}; // Generator vector for the first approximation.
00836
00837     try {
00838         gg = new mtk::Real[num_bndy_coeffs_];
00839     } catch (std::bad_alloc &memory_allocation_exception) {
00840         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00841         std::endl;
00842         std::cerr << memory_allocation_exception.what() << std::endl;
00843     }
00844     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00845
00846 #ifdef MTK_PRECISION_DOUBLE
00847     gg[1] = 1.0/2.0;
00848 #else
00849     gg[1] = 1.0f/2.0f;
00850 #endif
00851
00852 for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00853     gg[ii] = gg[ii - 1] + mtk::kOne;
00854 }
00855
00856 #if MTK_DEBUG_LEVEL > 0
00857 std::cout << "gg0 =" << std::endl;
00858 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00859     std::cout << std::setw(12) << gg[ii];
00860 }
00861 std::cout << std::endl << std::endl;

```

```

00863 #endif
00864
00865 // Allocate 2D array to store the collection of preliminary approximations.
00866 try {
00867     prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00868 } catch (std::bad_alloc &memory_allocation_exception) {
00869     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00870 std::endl;
00871     std::cerr << memory_allocation_exception.what() << std::endl;
00872 }
00873 memset(prem_apps_,
00874         mtk::kZero,
00875         sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00876
00877 for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00878
00879     // Re-check new generator vector for every iteration except for the first.
00880     #if MTK_DEBUG_LEVEL > 0
00881     if (ll > 0) {
00882         std::cout << "gg" << ll << " =" << std::endl;
00883         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00884             std::cout << std::setw(12) << gg[ii];
00885         }
00886         std::cout << std::endl << std::endl;
00887     }
00888     #endif
00889
00890     bool transpose{false};
00891
00892     mtk::DenseMatrix aa(gg,
00893                         num_bndy_coeffs_, order_accuracy_ + 1,
00894                         transpose);
00895
00896     #if MTK_DEBUG_LEVEL > 0
00897     std::cout << "aa_" << ll << " =" << std::endl;
00898     std::cout << aa << std::endl;
00899     #endif
00900
00901     mtk::Real *ob{};
00902
00903     auto ob_ld = num_bndy_coeffs_;
00904
00905     try {
00906         ob = new mtk::Real[ob_ld];
00907     } catch (std::bad_alloc &memory_allocation_exception) {
00908         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00909 std::endl;
00910         std::cerr << memory_allocation_exception.what() << std::endl;
00911     }
00912     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00913
00914     ob[1] = mtk::kOne;
00915
00916     #if MTK_DEBUG_LEVEL > 0
00917     std::cout << "ob = " << std::endl << std::endl;
00918     for (auto ii = 0; ii < ob_ld; ++ii) {
00919         std::cout << std::setw(12) << ob[ii] << std::endl;
00920     }
00921     std::cout << std::endl;
00922     #endif
00923
00924     // However, this is an under-determined system of equations. So we can not
00925     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00926     // our LAPACKAdapter class.
00927
00928     int info_{
00929         mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
00930 , ob_ld)};
00931
00932     #if MTK_DEBUG_LEVEL > 0
00933     if (!info_) {
00934         std::cout << "System successfully solved!" << std::endl << std::endl;
00935     } else {
00936         std::cerr << "Error solving system! info = " << info_ << std::endl;
00937     }
00938     #endif
00939
00940
00941
00942
00943
00944
00945
00946

```

```

00947     #if MTK_DEBUG_LEVEL > 0
00948     std::cout << "ob =" << std::endl;
00949     for (auto ii = 0; ii < ob_ld; ++ii) {
00950         std::cout << std::setw(12) << ob[ii] << std::endl;
00951     }
00952     std::cout << std::endl;
00953     #endif
00954
00955
00956
00957     // This implies a DAXPY operation. However, we must construct the arguments
00958     // for this operation.
00959
00960
00961     // Save them into the ob_bottom array:
00962
00963     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00964
00965     try {
00966         ob_bottom = new mtk::Real[dim_null_];
00967     } catch (std::bad_alloc &memory_allocation_exception) {
00968         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00969             std::endl;
00970         std::cerr << memory_allocation_exception.what() << std::endl;
00971     }
00972     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00973
00974     for (auto ii = 0; ii < dim_null_; ++ii) {
00975         ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00976     }
00977
00978     #if MTK_DEBUG_LEVEL > 0
00979     std::cout << "ob_bottom =" << std::endl;
00980     for (auto ii = 0; ii < dim_null_; ++ii) {
00981         std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00982     }
00983     std::cout << std::endl;
00984     #endif
00985
00986
00987
00988     // We must computed an scaled ob, sob, using the scaled null-space in
00989     // rat_basis_null_space_.
00990     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00991     // or:                      ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00992     // thus:                    Y =      a*A      *x      +      b*Y (DAXPY).
00993
00994     #if MTK_DEBUG_LEVEL > 0
00995     std::cout << "Rational basis for the null-space:" << std::endl;
00996     std::cout << rat_basis_null_space_ << std::endl;
00997     #endif
00998
00999     mtk::Real alpha{-mtk::kOne};
01000     mtk::Real beta{mtk::kOne};
01001
01002     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
01003         ob_bottom, beta, ob);
01004
01005     #if MTK_DEBUG_LEVEL > 0
01006     std::cout << "scaled ob:" << std::endl;
01007     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01008         std::cout << std::setw(12) << ob[ii] << std::endl;
01009     }
01010     std::cout << std::endl;
01011     #endif
01012
01013     // We save the recently scaled solution, into an array containing these.
01014     // We can NOT start building the pi matrix, simply because I want that part
01015     // to be separated since its construction depends on the algorithm we want
01016     // to implement.
01017
01018     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01019         prem_apps_[ii*num_bndy_approxs_ + 11] = ob[ii];
01020     }
01021
01022     // After the first iteration, simply shift the entries of the last
01023     // generator vector used:
01024     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01025         gg[ii]--;
01026     }
01027
01028     // Garbage collection for this loop:
01029     delete[] ob;
01030     ob = nullptr;

```

```

01031
01032     delete[] ob_bottom;
01033     ob_bottom = nullptr;
01034 } // End of: for (ll = 0; ll < dim_null; ll++);
01035
01036 #if MTK_DEBUG_LEVEL > 0
01037 std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
01038 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01039     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01040         std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
01041     }
01042     std::cout << std::endl;
01043 }
01044 std::cout << std::endl;
01045 #endif
01046
01047 delete[] gg;
01048 gg = nullptr;
01049
01050 return true;
01051 }
01052
01053 bool mtk::Grad1D::ComputeWeights() {
01054
01055     // Matrix to compute the weights as in the CRSA.
01056     mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01057
01058     // Assemble the pi matrix using:
01059     // 1. The collection of scaled preliminary approximations.
01060     // 2. The collection of coefficients approximating at the interior.
01061     // 3. The scaled basis for the null-space.
01062
01063     // 1.1. Process array of scaled preliminary approximations.
01064
01065     // These are queued in scaled_solutions. Each one of these, will be a column
01066     // of the pi matrix:
01067     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01068         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01069             pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
01070                 prem_apps_[ii*num_bndy_approxs_ + jj];
01071         }
01072     }
01073
01074     // 1.2. Add columns from known stencil approximating at the interior.
01075
01076     // However, these must be padded by zeros, according to their position in the
01077     // final pi matrix:
01078     auto mm = 1;
01079     for (auto jj = num_bndy_approxs_; jj < order_accuracy_; ++jj) {
01080         for (auto ii = 0; ii < order_accuracy_; ++ii) {
01081             auto de = (ii + mm)*(2*(num_bndy_approxs_ - 1) +
01082                 (order_accuracy_/2 + 1)) + jj;
01083             pi.data()[de] = coeffs_interior_[ii];
01084         }
01085         ++mm;
01086     }
01087
01088     rat_basis_null_space_.OrderColMajor();
01089
01090     #if MTK_DEBUG_LEVEL > 0
01091     std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01092     std::cout << rat_basis_null_space_ << std::endl;
01093     #endif
01094
01095     // 1.3. Add final set of columns: rational basis for null-space.
01096
01097     for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
01098         jj < num_bndy_coeffs_ - 1; ++jj) {
01099         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01100             auto og =
01101                 (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
01102             auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
01103             pi.data()[de] = rat_basis_null_space_.data()[og];
01104         }
01105     }
01106
01107     #if MTK_DEBUG_LEVEL > 0
01108     std::cout << "coeffs_interior_" << std::endl;
01109     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01110         std::cout << std::setw(12) << coeffs_interior_[ii];
01111     }
01112

```

```

01113     }
01114     std::cout << std::endl << std::endl;
01115 #endif
01116
01117 #if MTK_DEBUG_LEVEL > 0
01118     std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01119     std::cout << pi << std::endl;
01120 #endif
01121
01122 // This imposes the mimetic condition.
01123
01124 mtk::Real *hh{}; // Right-hand side to compute weights in the C(R,B)SA.
01125
01126 try {
01127     hh = new mtk::Real[num_bndy_coeffs_];
01128 } catch (std::bad_alloc &memory_allocation_exception) {
01129     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01130         std::endl;
01131     std::cerr << memory_allocation_exception.what() << std::endl;
01132 }
01133
01134 memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01135
01136 hh[0] = -mtk::kOne;
01137 for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01138     auto aux_xx = mtk::kZero;
01139     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01140         aux_xx += coeffs_interior_[jj];
01141     }
01142     hh[ii] = -mtk::kOne*aux_xx;
01143 }
01144
01145 // That is, we construct a system, to solve for the weights.
01146
01147 // Once again we face the challenge of solving with LAPACK. However, for the
01148 // CRSA, this matrix PI is over-determined, since it has more rows than
01149 // unknowns. However, according to the theory, the solution to this system is
01150 // unique. We will use dgels_.
01151
01152 try {
01153     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01154 } catch (std::bad_alloc &memory_allocation_exception) {
01155     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01156         std::endl;
01157     std::cerr << memory_allocation_exception.what() << std::endl;
01158 }
01159
01160 memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01161
01162 int weights_ld{pi.num_cols() + 1};
01163
01164 // Preserve hh.
01165 std::copy(hh, hh + weights_ld, weights_cbs_);
01166
01167 pi.Transpose();
01168
01169 int info{
01170     mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01171         weights_cbs_, weights_ld)
01172 };
01173
01174 #if MTK_DEBUG_LEVEL > 0
01175 if (!info) {
01176     std::cout << "System successfully solved!" << std::endl << std::endl;
01177 } else {
01178     std::cerr << "Error solving system! info = " << info << std::endl;
01179 }
01180 #endif
01181
01182 #if MTK_DEBUG_LEVEL > 0
01183 std::cout << "hh =" << std::endl;
01184 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01185     std::cout << std::setw(11) << hh[ii] << std::endl;
01186 }
01187 std::cout << std::endl;
01188 #endif
01189
01190 // Preserve the original weights for research.
01191
01192 try {
01193     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_DEBUG_LEVEL > 0
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     int minrow{std::numeric_limits<int>::infinity()};
01215     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
01216     order_accuracy_)};
01217     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01218
01219     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01220
01221     // 6.1. Insert preliminary approximations to first set of columns.
01222     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01223         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01224             phi.data()[ii*(order_accuracy_ + 1) + jj] =
01225                 prem_apps_[ii*num_bndy_approxs_ + jj];
01226         }
01227     }
01228
01229     // 6.2. Skip a column and negate preliminary approximations.
01230     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01231         for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01232             auto de = (ii + order_accuracy_ - num_bndy_approxs_ + jj*order_accuracy_);
01233             auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01234             phi.data()[de] = -premier_apps_[og];
01235         }
01236     }
01237
01238     // 6.3. Flip negative columns up-down.
01239     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01240         for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01241             auto aux = phi.data()[ii*order_accuracy_ + jj];
01242             phi.data()[ii*order_accuracy_ + jj] =
01243                 phi.data()[ (order_accuracy_ - ii)*order_accuracy_ + jj];
01244             phi.data()[ (order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01245         }
01246     }
01247
01248     // 6.4. Insert stencil.
01249     auto mm = 0;
01250     for (auto jj = num_bndy_approxs_; jj < num_bndy_approxs_ + 1; jj++) {
01251         for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01252             if (ii == 0) {
01253                 phi.data()[jj] = 0.0;
01254             } else {
01255                 phi.data()[ (ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01256             }
01257             mm++;
01258         }
01259     }
01260
01261     #if MTK_DEBUG_LEVEL > 0
01262     std::cout << "phi =" << std::endl;
01263     std::cout << phi << std::endl;
01264     #endif
01265
01266     mtk::Real *lamed{}; // Used to build big lambda.
01267
01268
01269

```

```

01279     try {
01280         lamed = new mtk::Real[num_bndy_approxs_ - 1];
01281     } catch (std::bad_alloc &memory_allocation_exception) {
01282         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01283             std::endl;
01284         std::cerr << memory_allocation_exception.what() << std::endl;
01285     }
01286     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01287
01288     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01289         lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01290     }
01291
01292     #if MTK_DEBUG_LEVEL > 0
01293     std::cout << "lamed =" << std::endl;
01294     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01295         std::cout << std::setw(12) << lamed[ii] << std::endl;
01296     }
01297     std::cout << std::endl;
01298     #endif
01299
01300     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01301         mtk::Real temp = mtk::kZero;
01302         for (auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01303             temp = temp +
01304                 lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01305         }
01306         hh[ii] = hh[ii] - temp;
01307     }
01308
01309     #if MTK_DEBUG_LEVEL > 0
01310     std::cout << "big_lambda =" << std::endl;
01311     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01312         std::cout << std::setw(12) << hh[ii] << std::endl;
01313     }
01314     std::cout << std::endl;
01315     #endif
01316
01317     int copy_result{}; // Should I replace the solution... not for now.
01318
01319     mtk::Real normerr_; // Norm of the error for the solution on each row.
01320
01321     for (auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01322         normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01323 data(),
01324                                     order_accuracy_ + 1,
01325                                     order_accuracy_,
01326                                     order_accuracy_,
01327                                     hh,
01328                                     weights_cbs_,
01329                                     row_,
01330                                     mimetic_threshold_,
01331                                     copy_result);
01332
01333         mtk::Real aux{normerr_/norm};
01334
01335         #if MTK_DEBUG_LEVEL>0
01336         std::cout << "Relative norm: " << aux << " " << std::endl;
01337         std::cout << std::endl;
01338         #endif
01339
01340         if (aux < minnorm) {
01341             minnorm = aux;
01342             minrow_ = row_;
01343         }
01344     }
01345
01346     #if MTK_DEBUG_LEVEL > 0
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
01360

```



```

01361     #if MTK_DEBUG_LEVEL > 0
01362     std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01363         minrow_ + 1 << std::endl;
01364     std::cout << std::endl;
01365     #endif
01366
01367     copy_result = 1;
01368     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
data(),
01369                                     order_accuracy_ + 1,
01370                                     order_accuracy_,
01371                                     order_accuracy_,
01372                                     hh,
01373                                     weights_cbs_,
01374                                     minrow_,
01375                                     mimetic_threshold_,
01376                                     copy_result);
01377     mtk::Real aux_{normerr_/norm};
01378     #if MTK_DEBUG_LEVEL > 0
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_DEBUG_LEVEL > 0
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     memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01413
01414     for (auto ii = 0; ii < dim_null_; ++ii) {
01415         lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01416     }
01417
01418     #if MTK_DEBUG_LEVEL > 0
01419     std::cout << "lambda =" << std::endl;
01420     for (auto ii = 0; ii < dim_null_; ++ii) {
01421         std::cout << std::setw(12) << lambda[ii] << std::endl;
01422     }
01423     std::cout << std::endl;
01424     #endif
01425
01426     mtk::Real *alpha{}; // Collection of alpha values.
01427
01428     try {
01429         alpha = new mtk::Real[dim_null_];
01430     } catch (std::bad_alloc &memory_allocation_exception) {
01431         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01432             std::endl;
01433         std::cerr << memory_allocation_exception.what() << std::endl;
01434     }
01435     memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01436
01437     for (auto ii = 0; ii < dim_null_; ++ii) {
01438         alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01439     }

```

```

01443     }
01444
01445     #if MTK_DEBUG_LEVEL > 0
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     try {
01454         mim_bndy_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
01455     } catch (std::bad_alloc &memory_allocation_exception) {
01456         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01457             std::endl;
01458         std::cerr << memory_allocation_exception.what() << std::endl;
01459     }
01460     memset(mim_bndy_,
01461         mtk::kZero,
01462         sizeof(mim_bndy_[0])*num_bndy_coeffs_*num_bndy_approxs_);
01463
01464     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01465         for (auto jj = 0; jj < (num_bndy_approxs_ - 1); ++jj) {
01466             mim_bndy_[ii*num_bndy_approxs_ + jj] =
01467                 prem_apps_[ii*num_bndy_approxs_ + jj] +
01468                 alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01469         }
01470     }
01471
01472     for(auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01473         mim_bndy_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)] =
01474             prem_apps_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)];
01475     }
01476
01477     #if MTK_DEBUG_LEVEL > 0
01478     std::cout << "Collection of mimetic approximations:" << std::endl;
01479     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01480         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01481             std::cout << std::setw(13) << mim_bndy_[ii*num_bndy_approxs_ + jj];
01482         }
01483         std::cout << std::endl;
01484     }
01485     std::cout << std::endl;
01486     #endif
01487
01488     delete[] lambda;
01489     lambda = nullptr;
01490
01491     delete[] alpha;
01492     alpha = nullptr;
01493
01494     return true;
01495 }
01496
01497 bool mtk::Grad1D::AssembleOperator(void) {
01498
01499     // The output array will have this form:
01500     // 1. The first entry of the array will contain the used order kk.
01501     // 2. The second entry of the array will contain the collection of
01502     // approximating coefficients for the interior of the grid.
01503     // 3. The third entry will contain a collection of weights.
01504     // 4. The next dim_null - 1 entries will contain the collections of
01505     // approximating coefficients for the west boundary of the grid.
01506
01507     gradient_length_ = 1 + order_accuracy_ + order_accuracy_ +
01508         num_bndy_approxs_*num_bndy_coeffs_;
01509
01510     #if MTK_DEBUG_LEVEL > 0
01511     std::cout << "gradient_length_ = " << gradient_length_ << std::endl;
01512     #endif
01513
01514     try {
01515         gradient_ = new mtk::Real[gradient_length_];
01516     } catch (std::bad_alloc &memory_allocation_exception) {
01517         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01518             std::endl;
01519         std::cerr << memory_allocation_exception.what() << std::endl;
01520     }
01521
01522     memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01523
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_DEBUG_LEVEL > 0
01563   std::cout << "1D " << order_accuracy_ << "-order grad built!" << std::endl;
01564   std::cout << std::endl;
01565   #endif
01566
01567   return true;
01568 }

```

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

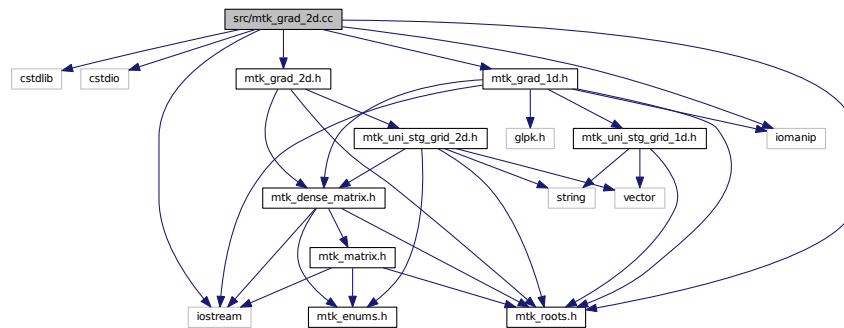
Implements the class Grad2D.

```

#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:



### 17.69.1 Detailed Description

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

#### Author

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

## 17.70 mtk\_grad\_2d.cc

```

00001
00011 /*
00012 Copyright (C) 2015, Computational Science Research Center, San Diego State
00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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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
00078     mtk::UniStgGrid2D &grid,
00079                                     int order_accuracy,
00079                                     mtk::Real mimetic_threshold) {
00080
00081     int num_cells_x = grid.num_cells_x();
00082     int num_cells_y = grid.num_cells_y();
00083
00084     int mx = num_cells_x + 1; // Gx vertical dimension
00085     int nx = num_cells_x + 2; // Gx horizontal dimension
00086     int my = num_cells_y + 1; // Gy vertical dimension
00087     int ny = num_cells_y + 2; // Gy horizontal dimension
00088
00089     mtk::Grad1D grad;
00090
00091     bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00092
00093     if (!info) {
00094         std::cerr << "Mimetic grad could not be built." << std::endl;
00095         return info;
00096     }
00097
00098     auto west = grid.west_bndy();
00099     auto east = grid.east_bndy();
00100     auto south = grid.south_bndy();
00101     auto north = grid.north_bndy();
00102
00103     mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00104     mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00105
00106     mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));
00107     mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00108
00109     bool padded{true};
00110     bool transpose{true};
00111
00112     mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00113     mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00114
00115     mtk::DenseMatrix gxy(mtk::DenseMatrix::Kron(tiy, Gx));
00116     mtk::DenseMatrix gyx(mtk::DenseMatrix::Kron(Gy, tix));
00117
00118     #if MTK_DEBUG_LEVEL > 0
00119     std::cout << "Gx: " << mx << " by " << nx << std::endl;
00120     std::cout << "Transpose Iy: " << num_cells_y << " by " << ny << std::endl;
00121     std::cout << "Gy: " << my << " by " << ny << std::endl;
00122     std::cout << "Transpose Ix: " << num_cells_x << " by " << nx << std::endl;
00123     std::cout << "Grad 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00124         nx*ny << std::endl;
00125     #endif
00126
00127     mtk::DenseMatrix g2d(mx*num_cells_y + my*num_cells_x, nx*ny);
00128
00129     for(auto ii = 0; ii < nx*ny; ii++) {
00130         for(auto jj = 0; jj < mx*num_cells_y; jj++) {
00131             g2d.SetValue(jj,ii, gxy.GetValue(jj,ii));
00132         }
00133         for(auto kk = 0; kk < my*num_cells_x; kk++) {
00134             g2d.SetValue(kk + mx*num_cells_y, ii, gyx.GetValue(kk,ii));
00135         }
00136     }
00137
00138     gradient_ = g2d;
00139
00140     return info;
00141 }
00142
00143 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix() const {
00144
00145     return gradient_;
00146 }

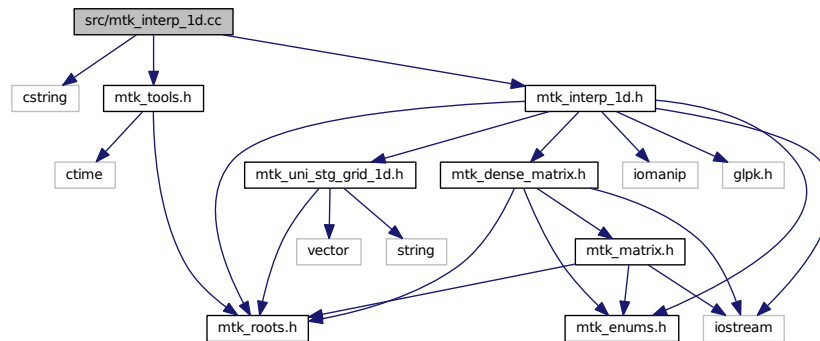
```

## 17.71 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)`

#### 17.71.1 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](#).

## 17.72 mtk\_interp\_1d.cc

```
00001
00012 /*
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00015
```

```

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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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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     stream << "coeffs_interior_[1:" << in.order_accuracy_ << "] = ";
00069     for (auto ii = 0; ii < in.order_accuracy_; ++ii) {
00070         stream << std::setw(9) << in.coeffs_interior_[ii] << " ";
00071     }
00072     stream << std::endl;
00073
00074     return stream;
00075 }
00076
00077 mtk::Interp1D::Interp1D():
00078     dir_interp_(mtk::SCALAR_TO_VECTOR),
00079     order_accuracy_(mtk::kDefaultOrderAccuracy),
00080     coeffs_interior_(nullptr) {}
00081
00082 mtk::Interp1D::Interp1D(const Interp1D &interp):
00083     dir_interp_(interp.dir_interp_),
00084     order_accuracy_(interp.order_accuracy_),
00085     coeffs_interior_(interp.coeffs_interior_) {}
00086
00087 mtk::Interp1D::~Interp1D() {
00088     delete[] coeffs_interior_;
00089     coeffs_interior_ = nullptr;
00090 }
00091
00092 bool mtk::Interp1D::ConstructInterp1D(int order_accuracy,
00093     mtk::DirInterp dir) {

```

```

00097
00098 #if MTK_DEBUG_LEVEL > 0
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
00105 std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00106 #endif
00107
00108 order_accuracy_ = order_accuracy;
00109
00110
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 mtk::Real *mtk::Interp1D::coeffs_interior() const {
00131
00132     return coeffs_interior_;
00133 }
00134
00135 mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix(
00136     const UniStgGrid1D &grid) const {
00137
00138     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00139
00140     #if MTK_DEBUG_LEVEL > 0
00141     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00142     #endif
00143
00144     int gg_num_rows{}; // Number of rows.
00145     int gg_num_cols{}; // Number of columns.
00146
00147     if (dir_interp_ == mtk::SCALAR_TO_VECTOR) {
00148         gg_num_rows = nn + 1;
00149         gg_num_cols = nn + 2;
00150     } else {
00151         gg_num_rows = nn + 2;
00152         gg_num_cols = nn + 1;
00153     }
00154
00155     // Output matrix featuring sizes for gradient operators.
00156
00157     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00158
00159     out.SetValue(0, 0, mtk::kOne);
00160
00161
00162
00163     for (auto ii = 1; ii < gg_num_rows - 1; ++ii) {
00164         for (auto jj = ii; jj < order_accuracy_ + ii; ++jj) {
00165             out.SetValue(ii, jj, mtk::kOne/order_accuracy_);
00166         }
00167     }
00168
00169
00170
00171
00172     out.SetValue(gg_num_rows - 1, gg_num_cols - 1, mtk::kOne);
00173
00174     return out;
00175 }
00176 }

```

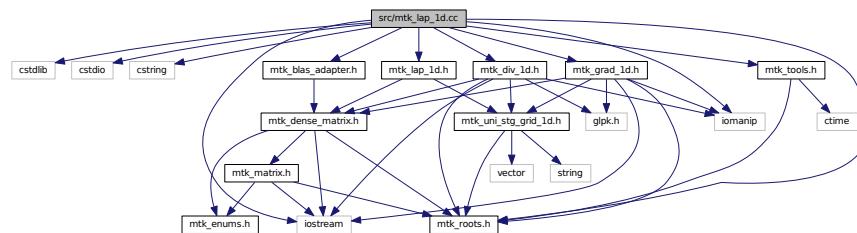


## 17.73 src/mtk\_lap\_1d.cc File Reference

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)`

### 17.73.1 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](#).

## 17.74 mtk\_lap\_1d.cc

00001

```

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00022 should be developed and included in any deliverable.
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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;

```

```

00095
00096     for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00097         for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00098             stream << std::setw(13) <<
00099                 in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00100         }
00101         stream << std::endl;
00102     }
00103
00104     return stream;
00105 }
00106 }
00107
00108 mtk::Lap1D::Lap1D():
00109     order_accuracy_(mtk::kDefaultOrderAccuracy),
00110     laplacian_length_(),
00111     mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00112
00113 mtk::Lap1D::~~Lap1D() {
00114
00115     delete [] laplacian_;
00116     laplacian_ = nullptr;
00117 }
00118
00119 bool mtk::Lap1D::ConstructLap1D(int order_accuracy,
00120                                 mtk::Real mimetic_threshold) {
00121
00122     #if MTK_DEBUG_LEVEL > 0
00123     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00124     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00125     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00126                         __FILE__, __LINE__, __func__);
00127
00128     if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00129         std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00130     }
00131
00132     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00133     std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00134     #endif
00135
00136     order_accuracy_ = order_accuracy;
00137     mimetic_threshold_ = mimetic_threshold;
00138
00139
00140
00141     mtk::Grad1D grad; // Mimetic gradient.
00142
00143     bool info = grad.ConstructGrad1D(order_accuracy_, mimetic_threshold_);
00144
00145     if (!info) {
00146         std::cerr << "Mimetic grad could not be built." << std::endl;
00147         return false;
00148     }
00149
00150
00151     mtk::Div1D div; // Mimetic divergence.
00152
00153     info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00154
00155     if (!info) {
00156         std::cerr << "Mimetic div could not be built." << std::endl;
00157         return false;
00158     }
00159
00160
00161
00162     // Since these are mimetic operator, we must multiply the matrices arising
00163     // from both the divergence and the Laplacian, in order to get the
00164     // approximating coefficients for the Laplacian operator.
00165
00166     // However, we must choose a grid that implied a step size of 1, so to get
00167     // the approximating coefficients, without being affected from the
00168     // normalization with respect to the grid.
00169
00170
00171     // Also, the grid must be of the minimum size to support the requested order
00172     // of accuracy. We must please the divergence.
00173
00174     mtk::UniStgGrid1D aux(mtk::kZero,
00175                           (mtk::Real) 3*order_accuracy_ - 1,
00176                           3*order_accuracy_ - 1);
00177
00178     #if MTK_DEBUG_LEVEL > 0

```

```

00179     std::cout << "aux =" << std::endl;
00180     std::cout << aux << std::endl;
00181     std::cout <<"aux.delta_x() = " << aux.delta_x() << std::endl;
00182     std::cout << std::endl;
00183     #endif
00184
00185     mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00186
00187     #if MTK_DEBUG_LEVEL > 0
00188     std::cout << "grad_m =" << std::endl;
00189     std::cout << grad_m << std::endl;
00190     #endif
00191
00192     mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00193
00194     #if MTK_DEBUG_LEVEL > 0
00195     std::cout << "div_m =" << std::endl;
00196     std::cout << div_m << std::endl;
00197     #endif
00198
00202
00203     mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00204
00205     lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00206
00207     #if MTK_DEBUG_LEVEL > 0
00208     std::cout << "lap =" << std::endl;
00209     std::cout << lap << std::endl;
00210     #endif
00211
00213
00215     // The output array will have this form:
00216     // 1. The first entry of the array will contain the used order kk.
00217     // 2. The second entry of the array will contain the collection of
00218     // approximating coefficients for the interior of the grid.
00219     // 3. The next entries will contain the collections of approximating
00220     // coefficients for the west boundary of the grid.
00221
00222     laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00223         (order_accuracy_ - 1)*(2*order_accuracy_);
00224
00225     #if MTK_DEBUG_LEVEL > 0
00226     std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00227     std::cout << std::endl;
00228     #endif
00229
00230     try {
00231         laplacian_ = new mtk::Real[laplacian_length_];
00232     } catch (std::bad_alloc &memory_allocation_exception) {
00233         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00234             std::endl;
00235         std::cerr << memory_allocation_exception.what() << std::endl;
00236     }
00237     memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00238
00241
00242     laplacian_[0] = order_accuracy_;
00243
00246
00247     for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00248         laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00249     }
00250
00252
00253     auto offset = 1 + (2*order_accuracy_ - 1);
00254
00255     for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00256         for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00257             laplacian_[offset + ii*(2*order_accuracy_) + jj] =
00258                 lap.GetValue(1 + ii, jj);
00259         }
00260     }
00261
00262     return true;
00263 }
00264
00265 mtk::DenseMatrix mtk::LaplD::ReturnAsDenseMatrix(
00266     const UniStgGrid1D &grid) const {
00267
00268     int nn{grid.num_cells_x()}; // Number of cells on the grid.

```

```

00269
00270 #if MTK_DEBUG_LEVEL > 0
00271 mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00272 mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00273 #endif
00274
00275 mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00276
00277 mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
dx^2.
00278
00280
00281 auto offset = (1 + 2*order_accuracy_ - 1);
00282
00283 for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00284     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00285         lap.SetValue(1 + ii,
00286                     jj,
00287                     idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00288     }
00289 }
00290
00292
00293 offset = 1 + (order_accuracy_ - 1);
00294
00295 int kk{1};
00296 for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00297     int mm{1};
00298     for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00299         lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00300         mm = mm + 1;
00301     }
00302     kk = kk + 1;
00303 }
00304
00306
00307 offset = (1 + 2*order_accuracy_ - 1);
00308
00309 auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00310
00311 auto ll = 1;
00312 auto rr = 1;
00313 for (auto ii = nn; ii > aux - 1; --ii) {
00314     auto cc = 0;
00315     for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00316         lap.SetValue(ii, jj, lap.GetValue(rr, cc));
00317         ++ll;
00318         ++cc;
00319     }
00320     rr++;
00321 }
00322
00329
00330 return lap;
00331 }
00332
00333 const mtk::Real* mtk::Lap1D::data(const UniStgGrid1D &grid) const {
00334
00335     mtk::DenseMatrix tmp;
00336
00337     tmp = ReturnAsDenseMatrix(grid);
00338
00339     return tmp.data();
00340 }

```

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

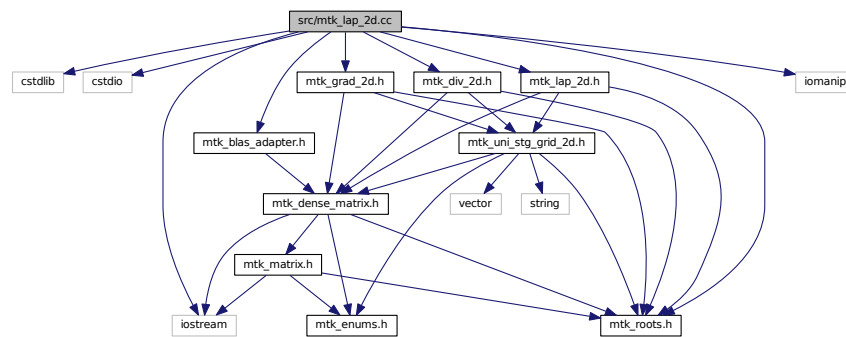
Includes the implementation of the class Lap2D.

```

#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:



### 17.75.1 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](#).

## 17.76 mtk\_lap\_2d.cc

```

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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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```

```

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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
00078     mtk::UniStgGrid2D &grid,
00079     int order_accuracy,
00080     mtk::Real mimetic_threshold) {
00081     mtk::Grad2D gg;
00082     mtk::Div2D dd;
00083
00084     bool info{gg.ConstructGrad2D(grid, order_accuracy, mimetic_threshold)};
00085
00086     if (!info) {
00087         std::cerr << "Mimetic lap could not be built." << std::endl;
00088         return info;
00089     }
00090
00091     info = dd.ConstructDiv2D(grid, order_accuracy, mimetic_threshold);
00092
00093     if (!info) {
00094         std::cerr << "Mimetic div could not be built." << std::endl;
00095         return info;
00096     }
00097
00098     mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00099     mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00100
00101     laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00102
00103     return info;
00104 }
00105
00106 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix() const {
00107     return laplacian_;
00108 }

```

```

00109 }
00110
00111 mtk::Real *mtk::Lap2D::data() const {
00112
00113     return laplacian_.data();
00114 }

```

## 17.77 src/mtk\_lapack\_adapter.cc File Reference

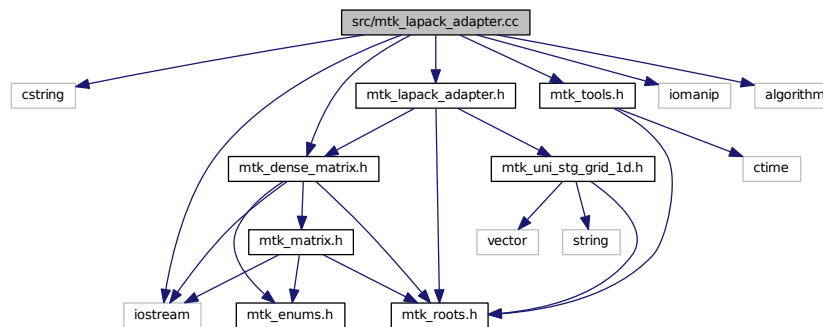
Adapter class for the LAPACK API.

```

#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.*



### 17.77.1 Detailed Description

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

## 17.78 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
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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     #if MTK_DEBUG_LEVEL > 0
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) {

```

```

00467
00468 int nrhs(bb.num_rows()); // Number of right-hand sides.
00469
00470 #if MTK_DEBUG_LEVEL > 0
00471 mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00472 #endif
00473
00474 int *ipiv{}; // Array for pivoting information.
00475 int info{}; // Status of the solution.
00476 int mm_rank{mm.num_rows()}; // Rank of the matrix.
00477
00478 try {
00479     ipiv = new int[mm_rank];
00480 } catch (std::bad_alloc &memory_allocation_exception) {
00481     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00482         std::endl;
00483     std::cerr << memory_allocation_exception.what() << std::endl;
00484 }
00485 memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00486
00487 int ldbb = mm_rank;
00488 int mm_ld = mm_rank;
00489
00490 #ifdef MTK_PRECISION_DOUBLE
00491 dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00492 #else
00493 fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00494 #endif
00495
00496 delete [] ipiv;
00497
00498 // After output, the data in the matrix will be column-major ordered.
00499
00500 bb.SetOrdering(mtk::COL_MAJOR);
00501
00502 #if MTK_DEBUG_LEVEL > 0
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_DEBUG_LEVEL > 0
00510 std::cout << "bb_row_maj_ord =" << std::endl;
00511 std::cout << bb << std::endl;
00512 #endif
00513
00514 return info;
00515 }
00516
00517 int mtk::LAPACKAdapter::SolveDenseSystem(
    mtk::DenseMatrix &mm,
    mtk::UniStgGrid1D &rhs) {
00518
00519     int nrhs{1}; // Number of right-hand sides.
00520
00521     int *ipiv{}; // Array for pivoting information.
00522     int info{}; // Status of the solution.
00523     int mm_rank{mm.num_rows()}; // Rank of the matrix.
00524
00525     try {
00526         ipiv = new int[mm_rank];
00527     } catch (std::bad_alloc &memory_allocation_exception) {
00528         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00529             std::endl;
00530         std::cerr << memory_allocation_exception.what() << std::endl;
00531     }
00532
00533     memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00534
00535     int ldbb = mm_rank;
00536     int mm_ld = mm_rank;
00537
00538     mm.OrderColMajor();
00539
00540 #ifdef MTK_PRECISION_DOUBLE
00541 dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00542     rhs.discrete_field_u(), &ldbb, &info);
00543 #else
00544 fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00545     rhs.discrete_field_u(), &ldbb, &info);
00546 #endif

```

```

00547
00548     mm.OrderRowMajor();
00549
00550     delete [] ipiv;
00551
00552     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_DEBUG_LEVEL > 0
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 MTK_DEBUG_LEVEL > 0
00593     if (info == 0) {
00594         lwork = (int) work[0];
00595     } else {
00596         std::cerr << "Could not get value for lwork on line " << __LINE__ - 5 <<
00597             std::endl;
00598         std::cerr << "Exiting..." << std::endl;
00599     }
00600     #endif
00601
00602     #if MTK_DEBUG_LEVEL>0
00603     std::cout << "lwork = " << std::endl << std::setw(12) << lwork << std::endl
00604         << std::endl;
00605     #endif
00606
00607     delete [] work;
00608     work = nullptr;
00609
00610     // Once we know lwork, we can actually invoke the factorization:
00611     try {
00612         work = new mtk::Real [lwork];
00613     } catch (std::bad_alloc &memory_allocation_exception) {
00614         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00615             std::endl;
00616         std::cerr << memory_allocation_exception.what() << std::endl;
00617     }
00618     memset(work, mtk::kZero, sizeof(work[0])*lwork);
00619
00620     int ltau = std::min(aaT_num_rows, aaT_num_cols);
00621
00622     try {
00623         tau = new mtk::Real [ltau];
00624     } catch (std::bad_alloc &memory_allocation_exception) {
00625         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00626             std::endl;

```

```

00627     std::cerr << memory_allocation_exception.what() << std::endl;
00628 }
00629 memset(tau, mtk::kZero, sizeof(0.0)*ltau);
00630
00631 #ifdef MTK_PRECISION_DOUBLE
00632 dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00633         tau, work, &lwork, &info);
00634 #else
00635 fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00636         tau, work, &lwork, &info);
00637 #endif
00638
00639 if (!info) {
00640     #if MTK_DEBUG_LEVEL > 0
00641         std::cout << "QR factorization completed!" << std::endl << std::endl;
00642     #endif
00643 } else {
00644     std::cerr << "Error solving system! info = " << info << std::endl;
00645     std::cerr << "Exiting..." << std::endl;
00646 }
00647
00648 #if MTK_DEBUG_LEVEL > 0
00649 std::cout << "Input matrix AFTER QR factorization:" << std::endl;
00650 std::cout << aa << std::endl;
00651 #endif
00652
00653 // We now generate the real matrix Q with orthonormal columns. This has to
00654 // be done separately since the actual output of dgeqrf_ (AA_) represents
00655 // the orthogonal matrix Q as a product of min(aa_num_rows,aa_num_cols)
00656 // elementary Householder reflectors. Notice that we must re-inquire the new
00657 // value for lwork that is used.
00658
00659 bool padded{false};
00660 bool transpose{false};
00661
00662 mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00663
00664 #if MTK_DEBUG_LEVEL > 0
00665 std::cout << "Initialized QQ_T: " << std::endl;
00666 std::cout << QQ_ << std::endl;
00667 #endif
00668
00669 // Assemble the QQ_ matrix:
00670 lwork = -1;
00671
00672 delete[] work;
00673 work = nullptr;
00674
00675 try {
00676     work = new mtk::Real[l];
00677 } catch (std::bad_alloc &memory_allocation_exception) {
00678     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00679     std::endl;
00680     std::cerr << memory_allocation_exception.what() <<
00681     std::endl;
00682 }
00683
00684 memset(work, mtk::kZero, sizeof(work[0])*l);
00685
00686 char side_{'L'};
00687 char trans_{'N'};
00688
00689 int aux = QQ_.num_rows();
00690
00691 #ifdef MTK_PRECISION_DOUBLE
00692 dormqr_(&side_, &trans_,
00693         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00694         QQ_.data(), &aux, work, &lwork, &info);
00695 #else
00696 formqr_(&side_, &trans_,
00697         &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00698         QQ_.data(), &aux, work, &lwork, &info);
00699 #endif
00700
00701 #if MTK_DEBUG_LEVEL > 0
00702 if (info == 0) {
00703     lwork = (int) work[0];
00704 } else {
00705     std::cerr << "Could not get lwork on line " << __LINE__ - 5 << std::endl;
00706     std::cerr << "Exiting..." << std::endl;
00707 }

```

```

00708 #endif
00709
00710 #if MTK_DEBUG_LEVEL > 0
00711 std::cout << "lwork = " << std::endl << std::setw(12) << lwork <<
00712     std::endl << std::endl;
00713 #endif
00714
00715 delete[] work;
00716 work = nullptr;
00717
00718 try {
00719     work = new mtk::Real[lwork];
00720 } catch (std::bad_alloc &memory_allocation_exception) {
00721     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00722         std::endl;
00723     std::cerr << memory_allocation_exception.what() << std::endl;
00724 }
00725 memset(work, mtk::kZero, sizeof(work[0])*lwork);
00726
00727 #ifdef MTK_PRECISION_DOUBLE
00728 dormqr_(&side_, &trans_,
00729     &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00730     QQ_.data(), &aux, work, &lwork, &info);
00731 #else
00732 formqr_(&side_, &trans_,
00733     &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00734     QQ_.data(), &aux, work, &lwork, &info);
00735 #endif
00736
00737 if (!info) {
00738     #if MTK_DEBUG_LEVEL>0
00739     std::cout << "Q matrix successfully assembled!" << std::endl << std::endl;
00740     #endif
00741 } else {
00742     std::cerr << "Something went wrong solving system! info = " << info <<
00743         std::endl;
00744     std::cerr << "Exiting..." << std::endl;
00745 }
00746
00747 delete[] work;
00748 work = nullptr;
00749
00750 delete[] tau;
00751 tau = nullptr;
00752
00753 return QQ_;
00754 }
00755
00756 int mtk::LAPACKAdapter::SolveRectangularDenseSystem(const
    mtk::DenseMatrix &aa,
                                mtk::Real *ob_,
                                int ob_ld_) {
00757
00758     // We first invoke the solver to query for the value of lwork. For this,
00759     // we must at least allocate enough space to allow access to WORK(1), or
00760     // work[0]:
00761
00762     // If LWORK = -1, then a workspace query is assumed; the routine only
00763     // calculates the optimal size of the WORK array, returns this value as
00764     // the first entry of the WORK array, and no error message related to
00765     // LWORK is issued by XERBLA.
00766
00767     mtk::Real *work{}; // Work array.
00768
00769     try {
00770         work = new mtk::Real[1];
00771     } catch (std::bad_alloc &memory_allocation_exception) {
00772         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00773         std::cerr << memory_allocation_exception.what() << std::endl;
00774     }
00775     memset(work, mtk::kZero, sizeof(work[0])*1);
00776
00777     char trans_{'N'};
00778     int nrhs_{1};
00779     int info{0};
00780     int lwork{-1};
00781
00782     int AA_num_rows_ = aa.num_cols();
00783     int AA_num_cols_ = aa.num_rows();
00784     int AA_ld_ = std::max(1, aa.num_cols());
00785
00786

```

```

00788  #ifdef MTK_PRECISION_DOUBLE
00789  dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00790        ob_, &ob_ld_,
00791        work, &lwork, &info);
00792  #else
00793  sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00794        ob_, &ob_ld_,
00795        work, &lwork, &info);
00796  #endif
00797
00798  if (info == 0) {
00799      lwork = (int) work[0];
00800  } else {
00801      std::cerr << "Could not get value for lwork on line " << __LINE__ - 2 <<
00802      std::endl;
00803      std::cerr << "Exiting..." << std::endl;
00804      return info;
00805  }
00806
00807  #if MTK_DEBUG_LEVEL > 0
00808  std::cout << "lwork = " << std::endl << std::setw(12)<< lwork <<
00809  std::endl << std::endl;
00810  #endif
00811
00812  // We then use lwork's new value to create the work array:
00813  delete[] work;
00814  work = nullptr;
00815
00816  try {
00817      work = new mtk::Real[lwork];
00818  } catch (std::bad_alloc &memory_allocation_exception) {
00819      std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00820      std::cerr << memory_allocation_exception.what() << std::endl;
00821  }
00822  memset(work, 0.0, sizeof(work[0])*lwork);
00823
00824  // We now invoke the solver again:
00825  #ifdef MTK_PRECISION_DOUBLE
00826  dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00827        ob_, &ob_ld_,
00828        work, &lwork, &info);
00829  #else
00830  sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00831        ob_, &ob_ld_,
00832        work, &lwork, &info);
00833  #endif
00834
00835  delete [] work;
00836  work = nullptr;
00837
00838  return info;
00839 }

```

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

Implementing the representation of a matrix in the MTK.

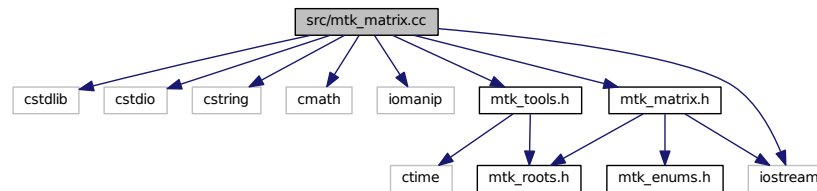
```

#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:



### 17.79.1 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](#).

## 17.80 mtk\_matrix.cc

```

00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
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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
00025
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00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
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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00036 specific prior written permission.
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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
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES

```

```

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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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
00190         mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
00191                                mtk::COL_MAJOR),
00192                                __FILE__, __LINE__, __func__);
00193     #endif
00194     ordering_ = oo;
00195 }

```

```

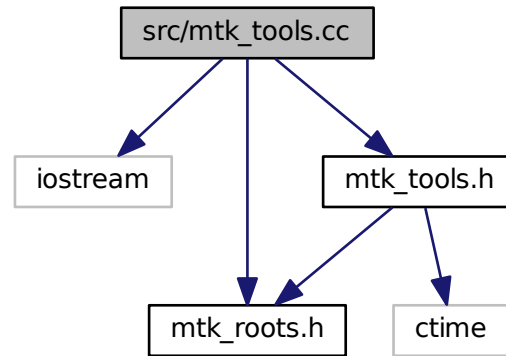
00208     ld_ = (ordering_ == mtk::ROW_MAJOR)?
00209         std::max(1,num_cols_): std::max(1,num_rows_);
00210 }
00211
00212 void mtk::Matrix::set_num_rows(const int &in) noexcept {
00213
00214     #if MTK_DEBUG_LEVEL > 0
00215     mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00216     #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     #if MTK_DEBUG_LEVEL > 0
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     #if MTK_DEBUG_LEVEL > 0
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
00250 void mtk::Matrix::set_num_null(const int &in) noexcept {
00251
00252     #if MTK_DEBUG_LEVEL > 0
00253     mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00254     #endif
00255
00256     num_null_ = in;
00257     num_non_null_ = num_values_ - num_null_;
00258
00259     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00260     abs_sparsity_ = 1.0 - abs_density_;
00261 }
00262
00263
00264 void mtk::Matrix::IncreaseNumZero() noexcept {
00265
00266
00267     num_zero_++;
00268     num_non_zero_ = num_values_ - num_zero_;
00269     rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00270     rel_sparsity_ = 1.0 - rel_density_;
00271 }
00272
00273
00274 void mtk::Matrix::IncreaseNumNull() noexcept {
00275
00276
00277     num_null_++;
00278     num_non_null_ = num_values_ - num_null_;
00279     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00280     abs_sparsity_ = 1.0 - abs_density_;
00281 }
00282 }

```

## 17.81 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:
```



### 17.81.1 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](#).

## 17.82 mtk\_tools.cc

```
00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
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00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
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
```

```

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00035 may be used to endorse or promote products derived from this software without
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057
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 MTK_DEBUG_LEVEL > 0
00067     if (lineno < 1) {
00070         std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00071         __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00072         exit(EXIT_FAILURE);
00073     }
00074     #endif
00075
00076     if (condition) {
00077         std::cerr << fname << ": " << "Incorrect parameter at line " <<
00078         lineno << " (" << fxname << ")" << std::endl;
00079         exit(EXIT_FAILURE);
00080     }
00081 }
00082
00083
00084
00085 int mtk::Tools::test_number_; // Used to control the correctness of the test.
00086
00087 mtk::Real mtk::Tools::duration_; // Duration of the current test.
00088
00089 clock_t mtk::Tools::begin_time_; // Used to time tests.
00090
00091 void mtk::Tools::BeginUnitTestNo(const int &nn) noexcept {
00092
00093     #if MTK_DEBUG_LEVEL > 0
00094     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00095     #endif
00096
00097     test_number_ = nn;
00098
00099     #if MTK_DEBUG_LEVEL > 0
00100     std::cout << "Beginning test " << nn << "." << std::endl;
00101     #endif
00102     begin_time_ = clock();
00103 }
00104
00105 void mtk::Tools::EndUnitTestNo(const int &nn) noexcept {
00106
00107     #if MTK_DEBUG_LEVEL > 0
00108     mtk::Tools::Prevent(test_number_ != nn, __FILE__, __LINE__, __func__);
00109     #endif
00110
00111     duration_ = mtk::Real(clock() - begin_time_)/CLOCKS_PER_SEC;
00112 }
00113
00114 void mtk::Tools::Assert(const bool &condition) noexcept {

```

```

00115
00116     if (condition) {
00117         std::cout << "Test " << test_number_ << ": PASSED in " << duration_ <<
00118             " s." << std::endl;
00119     } else {
00120         std::cout << "Test " << test_number_ << ": FAILED in " << duration_ <<
00121             " s." << std::endl;
00122     }
00123 }

```

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

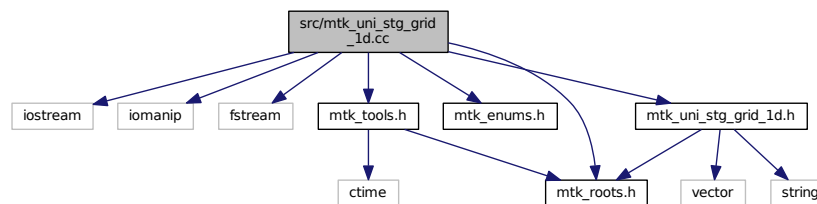
Implementation of an 1D uniform staggered grid.

```

#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)`

### 17.83.1 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](#).

## 17.84 mtk\_uni\_stg\_grid\_1d.cc

```

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00010 /*
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00012 University. All rights reserved.
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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
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
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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     stream << "x:";
00075     for (unsigned int ii = 0; ii < in.discrete_domain_x.size(); ++ii) {
00076         stream << std::setw(10) << in.discrete_domain_x[ii];
00077     }
00078     stream << std::endl;
00079
00080
00081     if (in.nature_ == mtk::SCALAR) {
00082         stream << "u:";
00083     }
00084     else {
00085         stream << "v:";
00086     }
00087
00088 }

```



```

00089     for (unsigned int ii = 0; ii < in.discrete_field_u_.size(); ++ii) {
00090         stream << std::setw(10) << in.discrete_field_u_[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_u_(),
00103     west_bndy_x_(),
00104     east_bndy_x_(),
00105     num_cells_x_(),
00106     delta_x_() {}
00107
00108 mtk::UniStgGrid1D::UniStgGrid1D(const
00109     UniStgGrid1D &grid):
00110     nature_(grid.nature_),
00111     west_bndy_x_(grid.west_bndy_x_),
00112     east_bndy_x_(grid.east_bndy_x_),
00113     num_cells_x_(grid.num_cells_x_),
00114     delta_x_(grid.delta_x_) {
00115
00116     std::copy(grid.discrete_domain_x_.begin(),
00117         grid.discrete_domain_x_.begin() + grid.
00118         discrete_domain_x_.size(),
00119         discrete_domain_x_.begin());
00120
00121     std::copy(grid.discrete_field_u_.begin(),
00122         grid.discrete_field_u_.begin() + grid.
00123         discrete_field_u_.size(),
00124         discrete_field_u_.begin());
00125 }
00126
00127 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00128     const Real &east_bndy_x,
00129     const int &num_cells_x,
00130     const mtk::FieldNature &nature) {
00131
00132     #if MTK_DEBUG_LEVEL > 0
00133     mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00134     mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00135     mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00136     mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00137     #endif
00138
00139     nature_ = nature;
00140     west_bndy_x_ = west_bndy_x;
00141     east_bndy_x_ = east_bndy_x;
00142     num_cells_x_ = num_cells_x;
00143
00144     delta_x_ = (east_bndy_x - west_bndy_x) / ((mtk::Real) num_cells_x);
00145 }
00146
00147 mtk::UniStgGrid1D::~~UniStgGrid1D() {}
00148
00149 mtk::Real mtk::UniStgGrid1D::west_bndy_x() const {
00150
00151     return west_bndy_x_;
00152 }
00153
00154 mtk::Real mtk::UniStgGrid1D::east_bndy_x() const {
00155
00156     return east_bndy_x_;
00157 }
00158
00159 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00160
00161     return delta_x_;
00162 }
00163
00164 const mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() const
00165 {
00166
00167     return discrete_domain_x_.data();
00168 }

```

```

00166 mtk::Real *mtk::UniStgGrid1D::discrete_field_u() {
00167
00168     return discrete_field_u_.data();
00169 }
00170
00171 int mtk::UniStgGrid1D::num_cells_x() const {
00172
00173     return num_cells_x_;
00174 }
00175
00176 void mtk::UniStgGrid1D::BindScalarField(
00177     mtk::Real (*ScalarField)(mtk::Real xx)) {
00178
00179     #if MTK_DEBUG_LEVEL > 0
00180     mtk::Tools::Prevent(nature_ == mtk::VECTOR, __FILE__, __LINE__, __func__);
00181     #endif
00182
00183
00184     discrete_domain_x_.reserve(num_cells_x_ + 2);
00185
00186     discrete_domain_x_.push_back(west_bndy_x_);
00187     #ifdef MTK_PRECISION_DOUBLE
00188     auto first_center = west_bndy_x_ + delta_x_/2.0;
00189     #else
00190     auto first_center = west_bndy_x_ + delta_x_/2.0f;
00191     #endif
00192     discrete_domain_x_.push_back(first_center);
00193     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00194         discrete_domain_x_.push_back(first_center + ii*delta_x_);
00195     }
00196     discrete_domain_x_.push_back(east_bndy_x_);
00197
00198
00199     discrete_field_u_.reserve(num_cells_x_ + 2);
00200
00201     discrete_field_u_.push_back(ScalarField(west_bndy_x_));
00202
00203     discrete_field_u_.push_back(ScalarField(first_center));
00204     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00205         discrete_field_u_.push_back(ScalarField(first_center + ii*delta_x_));
00206     }
00207     discrete_field_u_.push_back(ScalarField(east_bndy_x_));
00208 }
00209
00210 void mtk::UniStgGrid1D::BindVectorField(
00211     mtk::Real (*VectorField)(mtk::Real xx)) {
00212
00213     #if MTK_DEBUG_LEVEL > 0
00214     mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00215     #endif
00216
00217
00218     discrete_domain_x_.reserve(num_cells_x_ + 1);
00219
00220     discrete_domain_x_.push_back(west_bndy_x_);
00221     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00222         discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00223     }
00224     discrete_domain_x_.push_back(east_bndy_x_);
00225
00226
00227     discrete_field_u_.reserve(num_cells_x_ + 1);
00228
00229     discrete_field_u_.push_back(VectorField(west_bndy_x_));
00230     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00231         discrete_field_u_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00232     }
00233     discrete_field_u_.push_back(VectorField(east_bndy_x_));
00234 }
00235
00236 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00237     std::string space_name,
00238     std::string field_name) const {
00239
00240     std::ofstream output_dat_file; // Output file.
00241
00242     output_dat_file.open(filename);
00243
00244     if (!output_dat_file.is_open()) {
00245         return false;
00246     }
00247 }

```

```

00251
00252 output_dat_file << "# " << space_name << " ' " << field_name << std::endl;
00253 for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00254     output_dat_file << discrete_domain_x_[ii] << " ' " << discrete_field_u_[ii] <<
00255         std::endl;
00256 }
00257
00258 output_dat_file.close();
00259
00260 return true;
00261 }

```

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

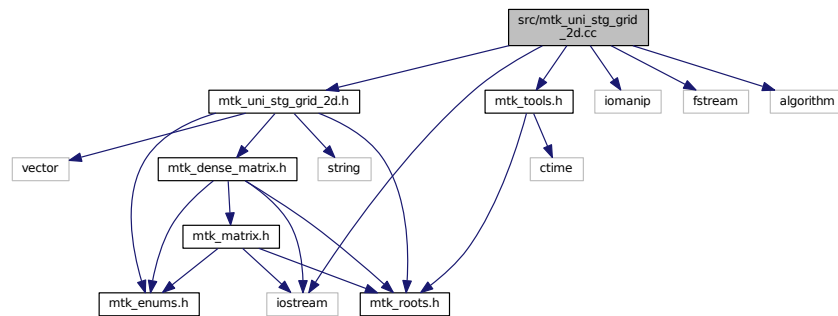
Implementation of a 2D uniform staggered grid.

```

#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)`

#### 17.85.1 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](#).

**17.86 mtk\_uni\_stg\_grid\_2d.cc**

```

00001
00010 /*
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00013
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00016
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
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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     stream << "x:";
00076
00077

```

```

00078     for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00079         stream << std::setw(10) << in.discrete_domain_x_[ii];
00080     }
00081     stream << std::endl;
00082
00083     stream << "y:";
00084     for (unsigned int ii = 0; ii < in.discrete_domain_y_.size(); ++ii) {
00085         stream << std::setw(10) << in.discrete_domain_y_[ii];
00086     }
00087     stream << std::endl;
00088
00090
00091     if (in.nature_ == mtk::SCALAR) {
00092         stream << "u:" << std::endl;
00093         if (in.discrete_field_.size() > 0) {
00094             for (int ii = 0; ii < in.num_cells_x_ + 2; ++ii) {
00095                 for (int jj = 0; jj < in.num_cells_y_ + 2; ++jj) {
00096                     stream << std::setw(10) << in.discrete_field_[ii*in.
num_cells_y_ + jj];
00097                 }
00098                 stream << std::endl;
00099             }
00100         }
00101     } else {
00102         int mm{in.num_cells_x_};
00103         int nn{in.num_cells_y_};
00104         int p_offset{nn*(mm + 1) - 1};
00105
00106         stream << "p(x,y):" << std::endl;
00107         for (int ii = 0; ii < nn; ++ii) {
00108             for (int jj = 0; jj < mm + 1; ++jj) {
00109                 stream << std::setw(10) << in.discrete_field_[ii*(mm + 1) + jj];
00110             }
00111             stream << std::endl;
00112         }
00113         stream << std::endl;
00114
00115         stream << "q(x,y):" << std::endl;
00116         for (int ii = 0; ii < nn + 1; ++ii) {
00117             for (int jj = 0; jj < mm; ++jj) {
00118                 stream << std::setw(10) <<
00119                     in.discrete_field_[p_offset + ii*mm + jj];
00120             }
00121             stream << std::endl;
00122         }
00123         stream << std::endl;
00124     }
00125 }
00126
00127 return stream;
00128 }
00129 }
00130
00131 mtk::UniStgGrid2D::UniStgGrid2D():
00132     discrete_domain_x_(),
00133     discrete_domain_y_(),
00134     discrete_field_(),
00135     nature_(),
00136     west_bndy_(),
00137     east_bndy_(),
00138     num_cells_x_(),
00139     delta_x_(),
00140     south_bndy_(),
00141     north_bndy_(),
00142     num_cells_y_(),
00143     delta_y_() {}
00144
00145 mtk::UniStgGrid2D::UniStgGrid2D(const
UniStgGrid2D &grid):
00146     nature_(grid.nature_),
00147     west_bndy_(grid.west_bndy_),
00148     east_bndy_(grid.east_bndy_),
00149     num_cells_x_(grid.num_cells_x_),
00150     delta_x_(grid.delta_x_),
00151     south_bndy_(grid.south_bndy_),
00152     north_bndy_(grid.north_bndy_),
00153     num_cells_y_(grid.num_cells_y_),
00154     delta_y_(grid.delta_y_) {
00155
00156     std::copy(grid.discrete_domain_x_.begin(),
00157         grid.discrete_domain_x_.begin() + grid.

```

```

        discrete_domain_x_.size(),
00158         discrete_domain_x_.begin());
00159
00160     std::copy(grid.discrete_domain_y_.begin(),
00161             grid.discrete_domain_y_.begin() + grid.
discrete_domain_y_.size(),
00162             discrete_domain_y_.begin());
00163
00164     std::copy(grid.discrete_field_.begin(),
00165             grid.discrete_field_.begin() + grid.discrete_field_.size(),
00166             discrete_field_.begin());
00167 }
00168
00169 mtk::UniStgGrid2D::UniStgGrid2D(const Real &west_bndy,
00170                                 const Real &east_bndy,
00171                                 const int &num_cells_x,
00172                                 const Real &south_bndy,
00173                                 const Real &north_bndy,
00174                                 const int &num_cells_y,
00175                                 const mtk::FieldNature &nature) {
00176
00177     #if MTK_DEBUG_LEVEL > 0
00178     mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00179     mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00180     mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00181     mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00182     mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00183     mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00184     mtk::Tools::Prevent(north_bndy <= south_bndy,
00185         __FILE__, __LINE__, __func__);
00186     mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00187     #endif
00188
00189     nature_ = nature;
00190
00191     west_bndy_ = west_bndy;
00192     east_bndy_ = east_bndy;
00193     num_cells_x_ = num_cells_x;
00194
00195     south_bndy_ = south_bndy;
00196     north_bndy_ = north_bndy;
00197     num_cells_y_ = num_cells_y;
00198
00199     delta_x_ = (east_bndy_ - west_bndy_) / ((mtk::Real) num_cells_x);
00200     delta_y_ = (north_bndy_ - south_bndy_) / ((mtk::Real) num_cells_y);
00201 }
00202
00203 mtk::UniStgGrid2D::~~UniStgGrid2D() {}
00204
00205 mtk::FieldNature mtk::UniStgGrid2D::nature() const {
00206
00207     return nature_;
00208 }
00209
00210 mtk::Real mtk::UniStgGrid2D::west_bndy() const {
00211
00212     return west_bndy_;
00213 }
00214
00215 mtk::Real mtk::UniStgGrid2D::east_bndy() const {
00216
00217     return east_bndy_;
00218 }
00219
00220 int mtk::UniStgGrid2D::num_cells_x() const {
00221
00222     return num_cells_x_;
00223 }
00224
00225 mtk::Real mtk::UniStgGrid2D::delta_x() const {
00226
00227     return delta_x_;
00228 }
00229
00230 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_x() const
00231 {
00232     return discrete_domain_x_.data();
00233 }
00234
00235 mtk::Real mtk::UniStgGrid2D::south_bndy() const {

```

```

00236
00237     return south_bndy_;
00238 }
00239
00240 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00241
00242     return north_bndy_;
00243 }
00244
00245 int mtk::UniStgGrid2D::num_cells_y() const {
00246
00247     return num_cells_y_;
00248 }
00249
00250 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00251
00252     return delta_y_;
00253 }
00254
00255 bool mtk::UniStgGrid2D::Bound() const {
00256
00257     return discrete_field_.size() != 0;
00258 }
00259
00260 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_y() const
00261 {
00262     return discrete_domain_y_.data();
00263 }
00264
00265 const mtk::Real* mtk::UniStgGrid2D::discrete_field() const {
00266
00267     return discrete_field_.data();
00268 }
00269
00270 void mtk::UniStgGrid2D::BindScalarField(Real (*ScalarField)(
00271     Real xx, Real yy)) {
00272
00273     #if MTK_DEBUG_LEVEL > 0
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
00292     discrete_domain_y_.reserve(num_cells_y_ + 2);
00293
00294     discrete_domain_y_.push_back(south_bndy_);
00295     #ifdef MTK_PRECISION_DOUBLE
00296     first_center = south_bndy_ + delta_x_/2.0;
00297     #else
00298     first_center = south_bndy_ + delta_x_/2.0f;
00299     #endif
00300     discrete_domain_y_.push_back(first_center);
00301     for (auto ii = 1; ii < num_cells_y_; ++ii) {
00302         discrete_domain_y_.push_back(first_center + ii*delta_y_);
00303     }
00304     discrete_domain_y_.push_back(north_bndy_);
00305
00306
00307     discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));
00308
00309     for (int ii = 0; ii < num_cells_x_ + 2; ++ii) {
00310         for (int jj = 0; jj < num_cells_y_ + 2; ++jj) {
00311             discrete_field_.push_back(ScalarField(discrete_domain_x_[ii],
00312                                                     discrete_domain_y_[jj]));
00313         }
00314     }
00315 }

```

```

00318 }
00319
00320 void mtk::UniStgGrid2D::BindVectorFieldPComponent (
00321     mtk::Real (*VectorField) (mtk::Real xx, mtk::Real yy)) {
00322
00323     int mm{num_cells_x_};
00324     int nn{num_cells_y_};
00325
00326     int total{nn*(mm + 1) + mm*(nn + 1)};
00327
00328     #ifdef MTK_PRECISION_DOUBLE
00329     double half_delta_x{delta_x_/2.0};
00330     double half_delta_y{delta_y_/2.0};
00331     #else
00332     float half_delta_x{delta_x_/2.0f};
00333     float half_delta_y{delta_y_/2.0f};
00334     #endif
00335
00337
00338     // We need every data point of the discrete domain; i.e. we need all the
00339     // nodes and all the centers. There are mm centers for the x direction, and
00340     // nn centers for the y direction. Since there is one node per center, that
00341     // amounts to 2*mm. If we finally consider the final boundary node, it
00342     // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00343     // y direction, this amounts to 2*nn + 1.
00344
00345     discrete_domain_x_.reserve(2*mm + 1);
00346
00347     discrete_domain_x_.push_back(west_bndy_);
00348     for (int ii = 1; ii < (2*mm + 1); ++ii) {
00349         discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00350     }
00351
00353
00354     discrete_domain_y_.reserve(2*nn + 1);
00355
00356     discrete_domain_y_.push_back(south_bndy_);
00357     for (int ii = 1; ii < (2*nn + 1); ++ii) {
00358         discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00359     }
00360
00362
00363     discrete_field_.reserve(total);
00364
00365     // For each y-center.
00366     for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00367
00368         // Bind all of the x-nodes for this y-center.
00369         for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00370             discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00371                                                     discrete_domain_y_[ii]));
00372
00373             #if MTK_DEBUG_LEVEL > 0
00374             std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00375                 discrete_domain_y_[ii] << " = " <<
00376                 VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00377             #endif
00378         }
00379     }
00380
00381     #if MTK_DEBUG_LEVEL > 0
00382     std::cout << std::endl;
00383     #endif
00384 }
00385
00386 void mtk::UniStgGrid2D::BindVectorFieldQComponent (
00387     mtk::Real (*VectorField) (mtk::Real xx, mtk::Real yy)) {
00388
00389     int mm{num_cells_x_};
00390     int nn{num_cells_y_};
00391
00392
00393     // For each y-node.
00394     for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00395
00396         // Bind all of the x-center for this y-node.
00397         for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00398             discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00399                                                     discrete_domain_y_[ii]));
00400
00401             #if MTK_DEBUG_LEVEL > 0
00402             std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<

```



```

00403         discrete_domain_y[ii] << " = " <<
00404         VectorField(discrete_domain_x[jj],discrete_domain_y[ii]) << std::endl;
00405     #endif
00406 }
00407 }
00408 #if MTK_DEBUG_LEVEL > 0
00409 std::cout << std::endl;
00410 #endif
00411 }
00412
00413 void mtk::UniStgGrid2D::BindVectorField(
00414     Real (*VectorFieldPComponent)(Real xx,Real yy),
00415     Real (*VectorFieldQComponent)(Real xx,Real yy)) {
00416
00417     #if MTK_DEBUG_LEVEL > 0
00418     mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00419     #endif
00420
00421     BindVectorFieldPComponent(VectorFieldPComponent);
00422     BindVectorFieldQComponent(VectorFieldQComponent);
00423 }
00424
00425 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00426     std::string space_name_x,
00427     std::string space_name_y,
00428     std::string field_name) const {
00429
00430     std::ofstream output_dat_file; // Output file.
00431
00432     output_dat_file.open(filename);
00433
00434     if (!output_dat_file.is_open()) {
00435         return false;
00436     }
00437
00438     if (nature_ == mtk::SCALAR) {
00439         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00440         field_name << std::endl;
00441
00442         for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00443             for (unsigned int jj = 0; jj < discrete_domain_y_.size(); ++jj) {
00444                 output_dat_file << discrete_domain_x_[ii] << ' ' <<
00445                 discrete_domain_y_[jj] << ' ' <<
00446                 discrete_field_[ii*discrete_domain_y_.size() + jj] <<
00447                 std::endl;
00448             }
00449             output_dat_file << std::endl;
00450         }
00451     } else {
00452         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00453         field_name << std::endl;
00454
00455         output_dat_file << "# Horizontal component:" << std::endl;
00456
00457         int mm{num_cells_x_};
00458         int nn{num_cells_y_};
00459
00460         // For each y-center.
00461         int idx{};
00462         for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00463             // Bind all of the x-nodes for this y-center.
00464             for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00465
00466                 output_dat_file << discrete_domain_x_[jj] << ' ' <<
00467                 discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<
00468                 mtk::kZero << std::endl;
00469
00470                 ++idx;
00471             }
00472         }
00473
00474         int p_offset{nn*(mm + 1) - 1};
00475         idx = 0;
00476         output_dat_file << "# Vertical component:" << std::endl;
00477         // For each y-node.
00478         for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00479             // Bind all of the x-center for this y-node.
00480             for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00481
00482                 output_dat_file << discrete_domain_x_[jj] << ' ' <<

```

```

00486         discrete_domain_y[ii] << ' ' << mtk::kZero << ' ' <<
00487         discrete_field_[p_offset + idx] << std::endl;
00488
00489         ++idx;
00490     }
00491 }
00492 }
00493
00494 output_dat_file.close();
00495
00496 return true;
00497 }

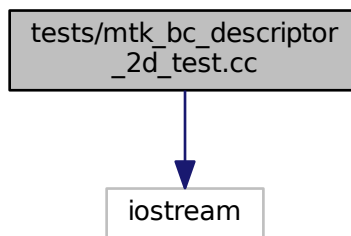
```

## 17.87 tests/mtk\_bc\_descriptor\_2d\_test.cc File Reference

Test file for the [mtk::BCDescriptor2D](#) class.

```
#include <iostream>
```

Include dependency graph for `mtk_bc_descriptor_2d_test.cc`:



### Functions

- int [main](#) ()

#### 17.87.1 Detailed Description

##### Author

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

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

#### 17.87.2 Function Documentation

##### 17.87.2.1 int main ( )

Definition at line [145](#) of file [mtk\\_bc\\_descriptor\\_2d\\_test.cc](#).

## 17.88 mtk\_bc\_descriptor\_2d\_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.
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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::BCDescriptor2D 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::BCDescriptor2D 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(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 int main () {
00134
00135     std::cout << "Testing mtk::BCDescriptor2D class." << std::endl;
00136
00137     TestDefaultConstructorGetters();
00138     TestPushBackImposeOnLaplacianMatrix();
00139 }
00140
00141 #else
00142 #include <iostream>
00143 using std::cout;
00144 using std::endl;
00145 int main () {
00146     cout << "This code HAS to be compiled with support for C++11." << endl;
00147     cout << "Exiting..." << endl;
00148 }
00149 #endif

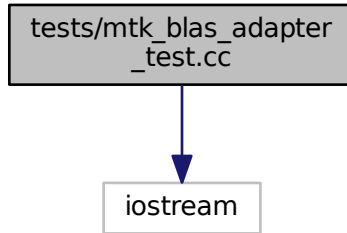
```

## 17.89 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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00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

```

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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

```

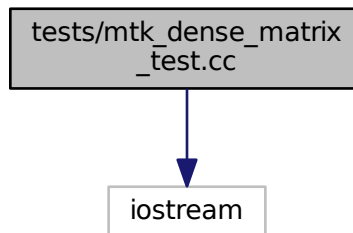
```
00105 #else
00106 #include <iostream>
00107 using std::cout;
00108 using std::endl;
00109 int main () {
00110     cout << "This code HAS to be compiled with support for C++11." << endl;
00111     cout << "Exiting..." << endl;
00112 }
00113 #endif
```

## 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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00016 and a copy of the modified files should be reported once modifications are
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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::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>

```

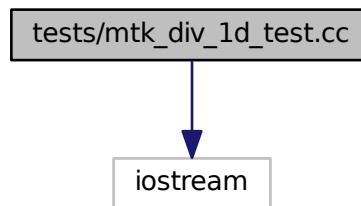
```
00328 using std::cout;
00329 using std::endl;
00330 int main () {
00331     cout << "This code HAS to be compiled with support for C++11." << endl;
00332     cout << "Exiting..." << endl;
00333 }
00334 #endif
```

## 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

00001

```

00008  /*
00009  Copyright (C) 2015, Computational Science Research Center, San Diego State
00010  University. All rights reserved.
00011
00012  Redistribution and use in source and binary forms, with or without modification,
00013  are permitted provided that the following conditions are met:
00014
00015  1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016  and a copy of the modified files should be reported once modifications are
00017  completed, unless these modifications are made through the project's GitHub
00018  page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019  should be developed and included in any deliverable.
00020
00021  2. Redistributions of source code must be done through direct
00022  downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024  3. Redistributions in binary form must reproduce the above copyright notice,
00025  this list of conditions and the following disclaimer in the documentation and/or
00026  other materials provided with the distribution.
00027
00028  4. Usage of the binary form on proprietary applications shall require explicit
00029  prior written permission from the the copyright holders, and due credit should
00030  be given to the copyright holders.
00031
00032  5. Neither the name of the copyright holder nor the names of its contributors
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00034  specific prior written permission.
00035
00036  The copyright holders provide no reassurances that the source code provided does
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00040  parties intellectual property rights.
00041
00042  THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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00049  ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050  (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051  SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052  */
00053
00054  #if __cplusplus == 201103L
00055
00056  #include <iostream>
00057
00058  #include "mtk.h"
00059
00060  void TestDefaultConstructorFactoryMethodDefault() {
00061
00062      mtk::Tools::BeginUnitTestNo(1);
00063
00064      mtk::Div1D div2;
00065
00066      bool assertion = div2.ConstructDiv1D();
00067
00068      if (!assertion) {
00069          std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00070      }
00071
00072      mtk::Tools::EndUnitTestNo(1);
00073      mtk::Tools::Assert(assertion);
00074  }
00075
00076  void TestDefaultConstructorFactoryMethodFourthOrder() {
00077
00078      mtk::Tools::BeginUnitTestNo(2);
00079
00080      mtk::Div1D div4;
00081
00082      bool assertion = div4.ConstructDiv1D(4);
00083
00084      if (!assertion) {
00085          std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00086      }
00087
00088      mtk::Tools::EndUnitTestNo(2);

```

```
00089     mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestDefaultConstructorFactoryMethodSixthOrder() {
00093
00094     mtk::Tools::BeginUnitTestNo(3);
00095
00096     mtk::Div1D div6;
00097
00098     bool assertion = div6.ConstructDiv1D(6);
00099
00100     if (!assertion) {
00101         std::cerr << "Mimetic div (6th order) could not be built." << std::endl;
00102     }
00103
00104     mtk::Tools::EndUnitTestNo(3);
00105     mtk::Tools::Assert(assertion);
00106 }
00107
00108 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00109
00110     mtk::Tools::BeginUnitTestNo(4);
00111
00112     mtk::Div1D div8;
00113
00114     bool assertion = div8.ConstructDiv1D(8);
00115
00116     if (!assertion) {
00117         std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00118     }
00119
00120     mtk::Tools::EndUnitTestNo(4);
00121     mtk::Tools::Assert(assertion);
00122 }
00123
00124 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00125
00126     mtk::Tools::BeginUnitTestNo(5);
00127
00128     mtk::Div1D div10;
00129
00130     bool assertion = div10.ConstructDiv1D(10);
00131
00132     if (!assertion) {
00133         std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00134     }
00135
00136     mtk::Tools::EndUnitTestNo(5);
00137     mtk::Tools::Assert(assertion);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142     mtk::Tools::BeginUnitTestNo(6);
00143
00144     mtk::Div1D div12;
00145
00146     bool assertion = div12.ConstructDiv1D(12);
00147
00148     if (!assertion) {
00149         std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00150     }
00151
00152     mtk::Tools::EndUnitTestNo(6);
00153     mtk::Tools::Assert(assertion);
00154 }
00155
00156 void TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold() {
00157
00158     mtk::Tools::BeginUnitTestNo(7);
00159
00160     mtk::Div1D div14;
00161
00162     bool assertion = div14.ConstructDiv1D(14);
00163
00164     if (!assertion) {
00165         std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00166     }
00167
00168     mtk::Tools::EndUnitTestNo(7);
00169     mtk::Tools::Assert(assertion);
```

```

00170 }
00171
00172 void TestSecondOrderReturnAsDenseMatrixWithGrid() {
00173     mtk::Tools::BeginUnitTestNo(8);
00174
00175     mtk::Div1D div2;
00176
00177     bool assertion = div2.ConstructDiv1D();
00178
00179     if (!assertion) {
00180         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00181     }
00182
00183     mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00184
00185     mtk::DenseMatrix div2m(div2.ReturnAsDenseMatrix(grid));
00186
00187     int rr{7};
00188     int cc{6};
00189
00190     mtk::DenseMatrix ref(rr, cc);
00191
00192     // Row 2.
00193     ref.SetValue(1,0,-5.0);
00194     ref.SetValue(1,1,5.0);
00195     ref.SetValue(1,2,0.0);
00196     ref.SetValue(1,3,0.0);
00197     ref.SetValue(1,4,0.0);
00198     ref.SetValue(1,5,0.0);
00199     ref.SetValue(1,6,0.0);
00200
00201     // Row 3.
00202     ref.SetValue(2,0,0.0);
00203     ref.SetValue(2,1,-5.0);
00204     ref.SetValue(2,2,5.0);
00205     ref.SetValue(2,3,0.0);
00206     ref.SetValue(2,4,0.0);
00207     ref.SetValue(2,5,0.0);
00208     ref.SetValue(2,6,0.0);
00209
00210     // Row 4.
00211     ref.SetValue(3,0,0.0);
00212     ref.SetValue(3,1,0.0);
00213     ref.SetValue(3,2,-5.0);
00214     ref.SetValue(3,3,5.0);
00215     ref.SetValue(3,4,0.0);
00216     ref.SetValue(3,5,0.0);
00217     ref.SetValue(3,6,0.0);
00218
00219     // Row 5.
00220     ref.SetValue(4,0,0.0);
00221     ref.SetValue(4,1,0.0);
00222     ref.SetValue(4,2,0.0);
00223     ref.SetValue(4,3,-5.0);
00224     ref.SetValue(4,4,5.0);
00225     ref.SetValue(4,5,0.0);
00226     ref.SetValue(4,6,0.0);
00227
00228     // Row 6.
00229     ref.SetValue(5,0,0.0);
00230     ref.SetValue(5,1,0.0);
00231     ref.SetValue(5,2,0.0);
00232     ref.SetValue(5,3,0.0);
00233     ref.SetValue(5,4,-5.0);
00234     ref.SetValue(5,5,5.0);
00235     ref.SetValue(5,6,0.0);
00236
00237     assertion = assertion && (div2m == ref);
00238
00239     mtk::Tools::EndUnitTestNo(8);
00240     mtk::Tools::Assert(assertion);
00241 }
00242
00243 void TestFourthOrderReturnAsDenseMatrixWithGrid() {
00244
00245     mtk::Tools::BeginUnitTestNo(9);
00246
00247     mtk::Div1D div4;
00248
00249     bool assertion = div4.ConstructDiv1D(4);
00250

```

```

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

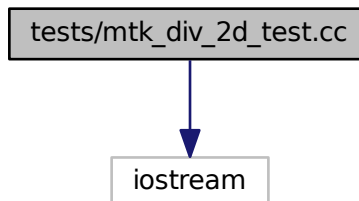
```

## 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

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
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00031
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00035
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00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

```

00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::Div2D dd;
00068
00069     mtk::Real aa = 0.0;
00070     mtk::Real bb = 1.0;
00071     mtk::Real cc = 0.0;
00072     mtk::Real ee = 1.0;
00073
00074     int nn = 5;
00075     int mm = 5;
00076
00077     mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00078
00079     bool assertion = dd.ConstructDiv2D(ddg);
00080
00081     if (!assertion) {
00082         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00083     }
00084
00085     mtk::Tools::EndUnitTestNo(1);
00086     mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091     mtk::Tools::BeginUnitTestNo(2);
00092
00093     mtk::Div2D dd;
00094
00095     mtk::Real aa = 0.0;
00096     mtk::Real bb = 1.0;
00097     mtk::Real cc = 0.0;
00098     mtk::Real ee = 1.0;
00099
00100     int nn = 5;
00101     int mm = 5;
00102
00103     mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00104
00105     bool assertion = dd.ConstructDiv2D(ddg);
00106
00107     if (!assertion) {
00108         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00109     }
00110
00111     mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00112
00113     assertion = assertion && (ddm.num_rows() != mtk::kZero);
00114
00115     std::cout << ddm << std::endl;
00116
00117     assertion = assertion && ddm.WriteToFile("mtk_div_2d_test_02.dat");
00118
00119     if(!assertion) {
00120         std::cerr << "Error writing to file." << std::endl;
00121     }
00122
00123     mtk::Tools::EndUnitTestNo(2);
00124     mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129     std::cout << "Testing mtk::Div2D class." << std::endl;
00130
00131     TestDefaultConstructorFactory();
00132     TestReturnAsDenseMatrixWriteToFile();
00133 }
00134

```

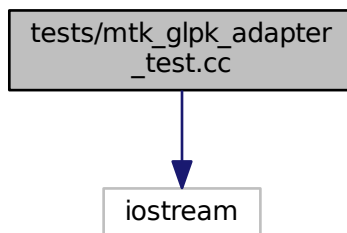
```
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140     cout << "This code HAS to be compiled with support for C++11." << endl;
00141     cout << "Exiting..." << endl;
00142 }
00143 #endif
```

## 17.97 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

```

00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
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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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00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072     std::cout << "Testing mtk::GLPKAdapter class." << std::endl;
00073
00074     Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082     cout << "This code HAS to be compiled with support for C++11." << endl;
00083     cout << "Exiting..." << endl;
00084 }
00085 #endif

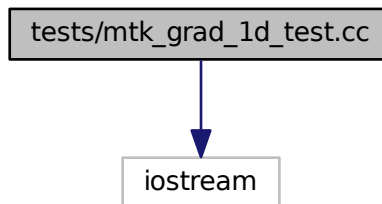
```

## 17.99 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 [296](#) of file [mtk\\_grad\\_1d\\_test.cc](#).

## 17.100 mtk\_grad\_1d\_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
```

```

00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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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::Grad1D grad2;
00063
00064     bool assertion = grad2.ConstructGrad1D();
00065
00066     if (!assertion) {
00067         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00068     }
00069
00070     std::cout << grad2 << std::endl;
00071
00072     mtk::Tools::EndUnitTestNo(1);
00073     mtk::Tools::Assert(assertion);
00074 }
00075
00076 void TestDefaultConstructorFactoryMethodFourthOrder() {
00077
00078     mtk::Tools::BeginUnitTestNo(2);
00079
00080     mtk::Grad1D grad4;
00081
00082     bool assertion = grad4.ConstructGrad1D(4);
00083
00084     if (!assertion) {
00085         std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00086     }
00087
00088     std::cout << grad4 << std::endl;
00089
00090     mtk::Tools::EndUnitTestNo(2);
00091     mtk::Tools::Assert(assertion);
00092 }
00093
00094 void TestDefaultConstructorFactoryMethodSixthOrder() {
00095
00096     mtk::Tools::BeginUnitTestNo(3);

```

```

00100
00101     mtk::Grad1D grad6;
00102
00103     bool assertion = grad6.ConstructGrad1D(6);
00104
00105     if (!assertion) {
00106         std::cerr << "Mimetic grad (6th order) could not be built." << std::endl;
00107     }
00108
00109     std::cout << grad6 << std::endl;
00110
00111     mtk::Tools::EndUnitTestNo(3);
00112     mtk::Tools::Assert(assertion);
00113 }
00114
00115 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00116
00117     mtk::Tools::BeginUnitTestNo(4);
00118
00119     mtk::Grad1D grad8;
00120
00121     bool assertion = grad8.ConstructGrad1D(8);
00122
00123     if (!assertion) {
00124         std::cerr << "Mimetic grad (8th order) could not be built." << std::endl;
00125     }
00126
00127     std::cout << grad8 << std::endl;
00128
00129     mtk::Tools::EndUnitTestNo(4);
00130     mtk::Tools::Assert(assertion);
00131 }
00132
00133 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00134
00135     mtk::Tools::BeginUnitTestNo(5);
00136
00137     mtk::Grad1D grad10;
00138
00139     bool assertion = grad10.ConstructGrad1D(10);
00140
00141     if (!assertion) {
00142         std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00143     }
00144
00145     std::cout << grad10 << std::endl;
00146
00147     mtk::Tools::EndUnitTestNo(5);
00148     mtk::Tools::Assert(assertion);
00149 }
00150
00151 void TestReturnAsDenseMatrixWithGrid() {
00152
00153     mtk::Tools::BeginUnitTestNo(6);
00154
00155     mtk::Grad1D grad2;
00156
00157     bool assertion = grad2.ConstructGrad1D();
00158
00159     if (!assertion) {
00160         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00161     }
00162
00163     mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00164
00165     mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00166
00167     int rr{6};
00168     int cc{7};
00169
00170     mtk::DenseMatrix ref(rr, cc);
00171
00172     // Row 1.
00173     ref.SetValue(0,0,-13.3333);
00174     ref.SetValue(0,1,15);
00175     ref.SetValue(0,2,-1.66667);
00176     ref.SetValue(0,3,0.0);
00177     ref.SetValue(0,4,0.0);
00178     ref.SetValue(0,5,0.0);
00179     ref.SetValue(0,6,0.0);
00180

```

```

00181 // Row 2.
00182 ref.SetValue(1,0,0.0);
00183 ref.SetValue(1,1,-5.0);
00184 ref.SetValue(1,2,5.0);
00185 ref.SetValue(1,3,0.0);
00186 ref.SetValue(1,4,0.0);
00187 ref.SetValue(1,5,0.0);
00188 ref.SetValue(1,6,0.0);
00189
00190 // Row 3.
00191 ref.SetValue(2,0,0.0);
00192 ref.SetValue(2,1,0.0);
00193 ref.SetValue(2,2,-5.0);
00194 ref.SetValue(2,3,5.0);
00195 ref.SetValue(2,4,0.0);
00196 ref.SetValue(2,5,0.0);
00197 ref.SetValue(2,6,0.0);
00198
00199 // Row 4.
00200 ref.SetValue(3,0,0.0);
00201 ref.SetValue(3,1,0.0);
00202 ref.SetValue(3,2,0.0);
00203 ref.SetValue(3,3,-5.0);
00204 ref.SetValue(3,4,5.0);
00205 ref.SetValue(3,5,0.0);
00206 ref.SetValue(3,6,0.0);
00207
00208 // Row 5.
00209 ref.SetValue(4,0,0.0);
00210 ref.SetValue(4,1,0.0);
00211 ref.SetValue(4,2,0.0);
00212 ref.SetValue(4,3,0.0);
00213 ref.SetValue(4,4,-5.0);
00214 ref.SetValue(4,5,5.0);
00215 ref.SetValue(4,6,0.0);
00216
00217 // Row 6.
00218 ref.SetValue(5,0,0.0);
00219 ref.SetValue(5,1,0.0);
00220 ref.SetValue(5,2,0.0);
00221 ref.SetValue(5,3,0.0);
00222 ref.SetValue(5,4,1.66667);
00223 ref.SetValue(5,5,-15.0);
00224 ref.SetValue(5,6,13.3333);
00225
00226 mtk::Tools::EndUnitTestNo(6);
00227 mtk::Tools::Assert(grad2m == ref);
00228 }
00229
00230 void TestReturnAsDimensionlessDenseMatrix() {
00231
00232     mtk::Tools::BeginUnitTestNo(7);
00233
00234     mtk::Grad1D grad4;
00235
00236     bool assertion = grad4.ConstructGrad1D(4);
00237
00238     if (!assertion) {
00239         std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00240     }
00241
00242     mtk::DenseMatrix grad4m(grad4.ReturnAsDimensionlessDenseMatrix
(10));
00243
00244     std::cout << grad4m << std::endl;
00245
00246     mtk::Tools::EndUnitTestNo(7);
00247     mtk::Tools::Assert(assertion);
00248 }
00249
00250 void TestWriteToFile() {
00251
00252     mtk::Tools::BeginUnitTestNo(8);
00253
00254     mtk::Grad1D grad2;
00255
00256     bool assertion = grad2.ConstructGrad1D();
00257
00258     if (!assertion) {
00259         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00260     }

```



```

00261
00262     mtk::UniStgGrid1D grid(0.0, 1.0, 50);
00263
00264     mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00265
00266     std::cout << grad2m << std::endl;
00267
00268     assertion = assertion && grad2m.WriteToFile("mtk_grad_1d_test_08.dat");
00269
00270     if(!assertion) {
00271         std::cerr << "Error writing to file." << std::endl;
00272     }
00273
00274     mtk::Tools::EndUnitTestNo(8);
00275     mtk::Tools::Assert(assertion);
00276 }
00277
00278 int main () {
00279
00280     std::cout << "Testing mtk::Grad1D class." << std::endl;
00281
00282     TestDefaultConstructorFactoryMethodDefault();
00283     TestDefaultConstructorFactoryMethodFourthOrder();
00284     TestDefaultConstructorFactoryMethodSixthOrder();
00285     TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00286     TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00287     TestReturnAsDenseMatrixWithGrid();
00288     TestReturnAsDimensionlessDenseMatrix();
00289     TestWriteToFile();
00290 }
00291
00292 #else
00293 #include <iostream>
00294 using std::cout;
00295 using std::endl;
00296 int main () {
00297     cout << "This code HAS to be compiled with support for C++11." << endl;
00298     cout << "Exiting..." << endl;
00299 }
00300 #endif

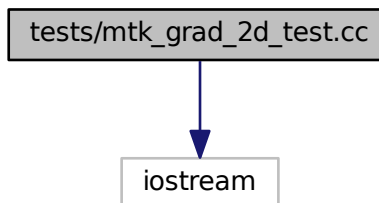
```

## 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

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

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
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00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00026 other materials provided with the distribution.
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00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

```

00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::Grad2D gg;
00068
00069     mtk::Real aa = 0.0;
00070     mtk::Real bb = 1.0;
00071     mtk::Real cc = 0.0;
00072     mtk::Real dd = 1.0;
00073
00074     int nn = 5;
00075     int mm = 5;
00076
00077     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00078
00079     bool assertion = gg.ConstructGrad2D(ggg);
00080
00081     if (!assertion) {
00082         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00083     }
00084
00085     mtk::Tools::EndUnitTestNo(1);
00086     mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091     mtk::Tools::BeginUnitTestNo(2);
00092
00093     mtk::Grad2D gg;
00094
00095     mtk::Real aa = 0.0;
00096     mtk::Real bb = 1.0;
00097     mtk::Real cc = 0.0;
00098     mtk::Real dd = 1.0;
00099
00100     int nn = 5;
00101     int mm = 5;
00102
00103     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00104
00105     bool assertion = gg.ConstructGrad2D(ggg);
00106
00107     if (!assertion) {
00108         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00109     }
00110
00111     mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00112
00113     assertion = assertion && (ggm.num_rows() != mtk::kZero);
00114
00115     std::cout << ggm << std::endl;
00116
00117     assertion = assertion && ggm.WriteToFile("mtk_grad_2d_test_02.dat");
00118
00119     if(!assertion) {
00120         std::cerr << "Error writing to file." << std::endl;
00121     }
00122
00123     mtk::Tools::EndUnitTestNo(2);
00124     mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129     std::cout << "Testing mtk::Grad2D class." << std::endl;
00130
00131     TestDefaultConstructorFactory();
00132     TestReturnAsDenseMatrixWriteToFile();
00133 }
00134

```

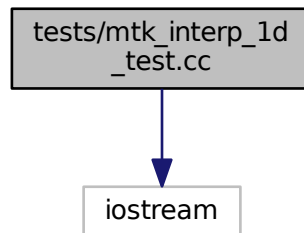
```
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140     cout << "This code HAS to be compiled with support for C++11." << endl;
00141     cout << "Exiting..." << endl;
00142 }
00143 #endif
```

### 17.103 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

```

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
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00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064     mtk::Tools::BeginUnitTestNo(1);
00065
00066     mtk::Interp1D inter;
00067
00068     bool assertion = inter.ConstructInterp1D();
00069
00070     if (!assertion) {
00071         std::cerr << "Mimetic interp could not be built." << std::endl;
00072     }
00073
00074     mtk::Tools::EndUnitTestNo(1);
00075     mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestReturnAsDenseMatrixWithGrid() {
00079
00080     mtk::Tools::BeginUnitTestNo(2);
00081
00082     mtk::Interp1D inter;
00083
00084     bool assertion = inter.ConstructInterp1D();
00085
00086     if (!assertion) {

```

```

00087     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00088 }
00089
00090 mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00091
00092 mtk::DenseMatrix interpm(inter.ReturnAsDenseMatrix(grid));
00093
00094 assertion =
00095     assertion && interpm.GetValue(0,0) == 1.0 && interpm.GetValue(5,6) == 1.0;
00096
00097 mtk::Tools::EndUnitTestNo(2);
00098 mtk::Tools::Assert(assertion);
00099 }
00100
00101 int main () {
00102
00103     std::cout << "Testing mtk::Interp1D class." << std::endl;
00104
00105     TestDefaultConstructorFactoryMethodDefault();
00106     TestReturnAsDenseMatrixWithGrid();
00107 }
00108
00109 #else
00110 #include <iostream>
00111 using std::cout;
00112 using std::endl;
00113 int main () {
00114     cout << "This code HAS to be compiled with support for C++11." << endl;
00115     cout << "Exiting..." << endl;
00116 }
00117 #endif

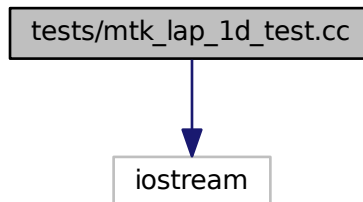
```

## 17.105 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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00012 University. All rights reserved.
00013
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00015 are permitted provided that the following conditions are met:
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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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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064     mtk::Tools::BeginUnitTestNo(1);
```

```
00065
00066     mtk::Lap1D lap2;
00067
00068     bool assertion = lap2.ConstructLap1D();
00069
00070     if (!assertion) {
00071         std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00072     }
00073
00074     mtk::Tools::EndUnitTestNo(1);
00075     mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestDefaultConstructorFactoryMethodFourthOrder() {
00079
00080     mtk::Tools::BeginUnitTestNo(2);
00081
00082     mtk::Lap1D lap4;
00083
00084     bool assertion = lap4.ConstructLap1D(4);
00085
00086     if (!assertion) {
00087         std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00088     }
00089
00090     mtk::Tools::EndUnitTestNo(2);
00091     mtk::Tools::Assert(assertion);
00092 }
00093
00094 void TestDefaultConstructorFactoryMethodSixthOrder() {
00095
00096     mtk::Tools::BeginUnitTestNo(3);
00097
00098     mtk::Lap1D lap6;
00099
00100     bool assertion = lap6.ConstructLap1D(6);
00101
00102     if (!assertion) {
00103         std::cerr << "Mimetic lap (6th order) could not be built." << std::endl;
00104     }
00105
00106     mtk::Tools::EndUnitTestNo(3);
00107     mtk::Tools::Assert(assertion);
00108 }
00109
00110 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00111
00112     mtk::Tools::BeginUnitTestNo(4);
00113
00114     mtk::Lap1D lap8;
00115
00116     bool assertion = lap8.ConstructLap1D(8);
00117
00118     if (!assertion) {
00119         std::cerr << "Mimetic lap (8th order) could not be built." << std::endl;
00120     }
00121
00122     mtk::Tools::EndUnitTestNo(4);
00123 }
00124
00125 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00126
00127     mtk::Tools::BeginUnitTestNo(5);
00128
00129     mtk::Lap1D lap10;
00130
00131     bool assertion = lap10.ConstructLap1D(10);
00132
00133     if (!assertion) {
00134         std::cerr << "Mimetic lap (10th order) could not be built." << std::endl;
00135     }
00136
00137     mtk::Tools::EndUnitTestNo(5);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142     mtk::Tools::BeginUnitTestNo(6);
00143
00144     mtk::Lap1D lap12;
00145
```



```

00146     bool assertion = lap12.ConstructLap1D(12);
00147
00148     if (!assertion) {
00149         std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00150     }
00151
00152     mtk::Tools::EndUnitTestNo(6);
00153 }
00154
00155 void TestReturnAsDenseMatrix() {
00156
00157     mtk::Tools::BeginUnitTestNo(8);
00158
00159     mtk::Lap1D lap4;
00160
00161     bool assertion = lap4.ConstructLap1D(4);
00162
00163     if (!assertion) {
00164         std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00165     }
00166
00167     mtk::UniStgGrid1D aux(0.0, 1.0, 11);
00168
00169     mtk::DenseMatrix lap4_m(lap4.ReturnAsDenseMatrix(aux));
00170
00171     assertion = assertion &&
00172         abs(lap4_m.GetValue(1, 0) - 385.133) < mtk::kDefaultTolerance &&
00173         abs(lap4_m.GetValue(11, 12) - 385.133) < mtk::kDefaultTolerance;
00174     mtk::Tools::EndUnitTestNo(8);
00175     mtk::Tools::Assert(assertion);
00176 }
00177
00178 int main () {
00179
00180     std::cout << "Testing MTK 1D Laplacian" << std::endl;
00181
00182     TestDefaultConstructorFactoryMethodDefault();
00183     TestDefaultConstructorFactoryMethodFourthOrder();
00184     TestDefaultConstructorFactoryMethodSixthOrder();
00185     TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00186     TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00187     TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00188     TestReturnAsDenseMatrix();
00189 }
00190
00191 #else
00192 #include <iostream>
00193 int main () {
00194     std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00195     std::cout << "Exiting..." << std::endl;
00196 }
00197 #endif

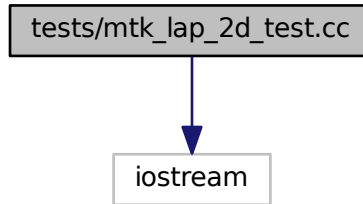
```

## 17.107 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](mailto:esanchez@mail.sdsu.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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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 #include <cmath>
00056 #include <ctime>
00057 #include <iostream>
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactory() {
00061     mtk::Tools::BeginUnitTestNo(1);
00062
00063     mtk::Lap2D ll;
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 llg(aa, bb, nn, cc, dd, mm);
00074
00075     bool assertion = ll.ConstructLap2D(llg);
00076
00077     if (!assertion) {
00078         std::cerr << "Mimetic lap (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::Lap2D ll;
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 llg(aa, bb, nn, cc, dd, mm);
00099
00100     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

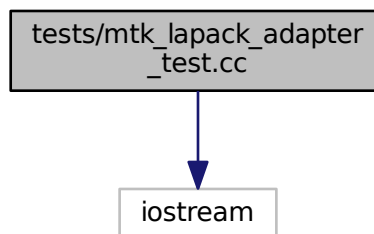
```

## 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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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
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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     mtk::Tools::BeginUnitTestNo(1);
00065     mtk::Tools::EndUnitTestNo(1);
00066 }
00067
00068 int main () {
00069     std::cout << "Testing mtk::LAPACKAdapter class." << std::endl;
00070     Test1();
00071 }
00072 #else
00073 #include <iostream>
00074 using std::cout;
00075 using std::endl;
00076 int main () {
00077     cout << "This code HAS to be compiled with support for C++11." << endl;
00078     cout << "Exiting..." << endl;
00079 }
00080 #endif

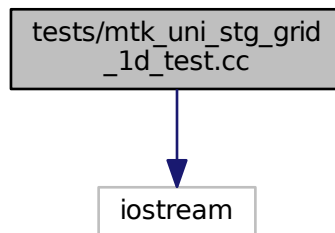
```

## 17.111 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 ()`

#### 17.111.1 Detailed Description

##### Author

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

Definition in file `mtk_uni_stg_grid_1d_test.cc`.

## 17.111.2 Function Documentation

### 17.111.2.1 int main ( )

Definition at line 172 of file [mtk\\_uni\\_stg\\_grid\\_1d\\_test.cc](#).

## 17.112 mtk\_uni\_stg\_grid\_1d\_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.
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructor() {
00062
00063     mtk::Tools::BeginUnitTestNo(1);
00064
00065     mtk::UniStgGrid1D gg;
00066
00067     mtk::Tools::EndUnitTestNo(1);
00068     mtk::Tools::Assert(gg.delta_x() == mtk::kZero);
00069 }
00070
00071 mtk::Real ScalarField(mtk::Real xx) {
00072
00073     return 2.0*xx;

```

```

00074 }
00075
00076 void TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField() {
00077     mtk::Tools::BeginUnitTestNo(2);
00078     mtk::Real aa = 0.0;
00080     mtk::Real bb = 1.0;
00081
00082     int nn = 5;
00083
00084     mtk::UniStgGrid1D gg(aa, bb, nn);
00085     gg.BindScalarField(ScalarField);
00086     std::cout << gg << std::endl;
00087
00088     mtk::Tools::EndUnitTestNo(2);
00089     mtk::Tools::Assert(gg.delta_x() == 0.2 && gg.
00090         num_cells_x() == 5);
00091 }
00092
00093 void TestBindScalarFieldWriteToFile() {
00094     mtk::Tools::BeginUnitTestNo(3);
00095     mtk::Real aa = 0.0;
00096     mtk::Real bb = 1.0;
00097
00098     int nn = 5;
00099
00100     mtk::UniStgGrid1D gg(aa, bb, nn);
00101     bool assertion{true};
00102     gg.BindScalarField(ScalarField);
00103
00104     assertion =
00105         assertion &&
00106         gg.discrete_field_u()[0] == 0.0 &&
00107         gg.discrete_field_u()[gg.num_cells_x() + 2 - 1] == 2.0;
00108
00109     if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_03.dat", "x", "u(x)")) {
00110         std::cerr << "Error writing to file." << std::endl;
00111         assertion = false;
00112     }
00113
00114     mtk::Tools::EndUnitTestNo(3);
00115     mtk::Tools::Assert(assertion);
00116 }
00117
00118 mtk::Real VectorFieldPComponent(mtk::Real xx) {
00119     return xx*xx;
00120 }
00121
00122 void TestBindVectorField() {
00123     mtk::Tools::BeginUnitTestNo(4);
00124     mtk::Real aa = 0.0;
00125     mtk::Real bb = 1.0;
00126
00127     int nn = 20;
00128
00129     mtk::UniStgGrid1D gg(aa, bb, nn, mtk::VECTOR);
00130     bool assertion{true};
00131     gg.BindVectorField(VectorFieldPComponent);
00132
00133     assertion =
00134         assertion &&
00135         gg.discrete_field_u()[0] == 0.0 &&
00136         gg.discrete_field_u()[gg.num_cells_x() + 1 - 1] == 1.0;
00137
00138     if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_04.dat", "x", "v(x)")) {
00139         std::cerr << "Error writing to file." << std::endl;
00140         assertion = false;
00141     }
00142
00143     mtk::Tools::EndUnitTestNo(4);
00144     mtk::Tools::Assert(assertion);
00145 }
00146
00147
00148
00149
00150
00151
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

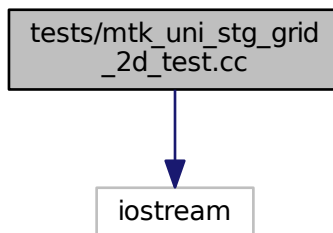
```

## 17.113 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 ()`

### 17.113.1 Detailed Description

#### Author

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Definition in file [mtk\\_uni\\_stg\\_grid\\_2d\\_test.cc](#).

## 17.113.2 Function Documentation

### 17.113.2.1 int main ( )

Definition at line 202 of file [mtk\\_uni\\_stg\\_grid\\_2d\\_test.cc](#).

## 17.114 mtk\_uni\_stg\_grid\_2d\_test.cc

```

00001
00008 /*
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00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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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 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

```

```

00073 void
00074 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOSTreamOperator() {
00075
00076     mtk::Tools::BeginUnitTestNo(2);
00077
00078     mtk::Real aa = 0.0;
00079     mtk::Real bb = 1.0;
00080     mtk::Real cc = 0.0;
00081     mtk::Real dd = 1.0;
00082
00083     int nn = 5;
00084     int mm = 7;
00085
00086     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00087
00088     std::cout << gg << std::endl;
00089
00090     mtk::Tools::EndUnitTestNo(2);
00091     mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00092         abs(gg.delta_y() - 0.142857) <
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(mtk::Real xx, 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(mtk::Real xx, mtk::Real yy) {

```

```

00153
00154     return xx + 0.01;
00155 }
00156
00157 mtk::Real VectorFieldQComponent(mtk::Real xx, mtk::Real yy) {
00158
00159     return yy + 0.01;
00160 }
00161
00162 void TestBindVectorField() {
00163
00164     mtk::Tools::BeginUnitTestNo(5);
00165
00166     mtk::Real aa = 0.0;
00167     mtk::Real bb = 1.0;
00168     mtk::Real cc = 0.0;
00169     mtk::Real dd = 1.0;
00170
00171     int nn = 5;
00172     int mm = 5;
00173
00174     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00175
00176     gg.BindVectorField(VectorFieldPComponent, VectorFieldQComponent);
00177
00178     std::cout << gg << std::endl;
00179
00180     if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_05.dat", "x", "y", "v(x,y)")) {
00181         std::cerr << "Error writing to file." << std::endl;
00182     }
00183
00184     mtk::Tools::EndUnitTestNo(5);
00185 }
00186
00187 int main () {
00188
00189     std::cout << "Testing mtk::UniStgGrid2D class." << std::endl;
00190
00191     TestDefaultConstructor();
00192     TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOSTreamOperator();
00193     TestGetters();
00194     TestBindScalarFieldWriteToFile();
00195     TestBindVectorField();
00196 }
00197
00198 #else
00199 #include <iostream>
00200 using std::cout;
00201 using std::endl;
00202 int main () {
00203     cout << "This code HAS to be compiled with support for C++11." << endl;
00204     cout << "Exiting..." << endl;
00205 }
00206 #endif

```

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