# MTK: Mimetic Methods Toolkit

Generated by Doxygen 1.8.8

Tue Nov 17 2015 16:24:45

# Contents

# Chapter 1

# Introduction

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

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

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

## 1.4 Acknowledgements and Contributions

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

1. Mohammad Abouali, Ph.D.
2. Dany De Cecchis, Ph.D.
3. 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



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

1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu and a copy of the modified files should be reported once modifications are completed, unless these modifications are made through the project's GitHub page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications should be developed and included in any deliverable.
2. Redistributions of source code must be done through direct downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
3. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
4. Usage of the binary form on proprietary applications shall require explicit prior written permission from the the copyright holders, and due credit should be given to the copyright holders.
5. Neither the name of the copyright holder nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

The copyright holders provide no reassurances that the source code provided does not infringe any patent, copyright, or any other intellectual property rights of third parties. The copyright holders disclaim any liability to any recipient for claims brought against recipient by any third party for infringement of that parties intellectual property rights.

THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

# Chapter 4

# Read Me File and Installation Instructions

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

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

### 1. Description

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

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

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

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

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

- testall: runs all the tests.

- gendoc: generates the documentation for the library.

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

**PART 2. BUILD THE LIBRARY.**

```
$ make
```

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

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

Examples and tests will also be built.

## 4. Frequently Asked Questions

Q: Why haven't you guys implemented GBS to build the library?
A: I'm on it as we speak! ;)

Q: Is there any main reference when it comes to the theory on Mimetic Methods?
A: Yes! Check: http://www.csrc.sdsu.edu/mimetic-book

Q: Do I need to generate the documentation myself?
A: You can if you want to... but if you DO NOT want to, just go to our website.

## 5. Contact, Support, and Credits

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

Developers are members of:

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

Currently the developers are:

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

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

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

Thanks and happy coding!

# Chapter 5

# Tests and Test Architectures

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

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

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

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

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

Further architectures will be tested!

# Chapter 6

# Examples

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

# Chapter 7

# User Manual, References and Theory

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

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

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

# Chapter 8

# Todo List

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

Implement Kronecker product using the BLAS.

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

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

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

Improve this so that no new ammays 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 ()**

Review the definition of sparse matrices properties.

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

Review the definition of sparse matrices properties.

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

Check if this is the best way of stalling execution.

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

Check usage of static methods and private members.

**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 (int in)**

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

**Member mtk::Matrix::set_num_zero (int in)**

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

# Chapter 10

# Module Index

## 10.1 Modules

Here is a list of all modules:

# Chapter 11

# Namespace Index

## 11.1 Namespace List

Here is a list of all namespaces with brief descriptions:

# Chapter 12

# Class Index

## 12.1 Class List

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

# Chapter 13

# File Index

## 13.1 File List

Here is a list of all files with brief descriptions:

# Chapter 14

# Module Documentation

## 14.1 Roots.

Fundamental execution parameters and defined types.

### Typedefs

- typedef float mtk::Real

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

### Variables

- const float mtk::kZero {0.0f}

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

  *MTK's one defined according to selective compilation.*
- const float mtk::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 157 of file mtk_roots.h.

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

Definition at line 166 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 147 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 133 of file mtk_roots.h.

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

Definition at line 121 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 108 of file mtk_roots.h.

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

**Warning**

Declared as double if MTK_PRECISION_DOUBLE is defined.

Definition at line 107 of file mtk_roots.h.

## 14.2 Enumerations.

Enumerations.

### Enumerations

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

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

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

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

  *Interpolation operator.*

### 14.2.1 Detailed Description

Enumerations.

### 14.2.2 Enumeration Type Documentation

#### 14.2.2.1 enum mtk::DirInterp

Used to tag different directions of interpolation supported.

**Enumerator**

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

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

Definition at line 127 of file mtk_enums.h.

#### 14.2.2.2 enum mtk::FieldNature

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

**See also**

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

**Enumerator**

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

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

Definition at line 113 of file mtk_enums.h.

#### 14.2.2.3 enum mtk::MatrixOrdering

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

**See also**

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

**Enumerator**

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

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

Definition at line 95 of file mtk_enums.h.

#### 14.2.2.4 enum mtk::MatrixStorage

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

**Enumerator**

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

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

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

Definition at line 77 of file mtk_enums.h.

## 14.3 Execution tools.

Tools to ensure execution correctness.

### Classes

- class mtk::Tools

  *Tool manager class.*

### 14.3.1 Detailed Description

Tools to ensure execution correctness.

## 14.4 Data structures.

Fundamental data structures.

### Classes

- class mtk::DenseMatrix

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

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

### 14.4.1 Detailed Description

Fundamental data structures.

## 14.5 Numerical methods.

Adapter classes and auxiliary numerical methods.

### Classes

- class mtk::BLASAdapter

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

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

  *Adapter class for the LAPACK API.*

### 14.5.1 Detailed Description

Adapter classes and auxiliary numerical methods.

## 14.6 Grids.

Uniform rectangular staggered grids.

### Classes

- class mtk::UniStgGrid1D

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

  *Uniform 2D Staggered Grid.*

### 14.6.1 Detailed Description

Uniform rectangular staggered grids.

## 14.7 Mimetic operators.

Mimetic operators.

### Classes

- class mtk::Div1D

  *Implements a 1D mimetic divergence operator.*
- class mtk::Grad1D

  *Implements a 1D mimetic gradient operator.*
- class mtk::Interp1D

  *Implements a 1D interpolation operator.*
- class mtk::Lap1D

  *Implements a 1D mimetic Laplacian operator.*
- class mtk::Quad1D

  *Implements a 1D mimetic quadrature.*

### 14.7.1 Detailed Description

Mimetic operators.

# Chapter 15

# Namespace Documentation

## 15.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

### Classes

- class BCDescriptor1D
- class BCDescriptor2D
- 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
- class GLPKAdapter

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

  *Implements a 1D mimetic gradient operator.*
- class Grad2D
- class Interp1D

  *Implements a 1D interpolation operator.*
- class Interp2D
- class Lap1D

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

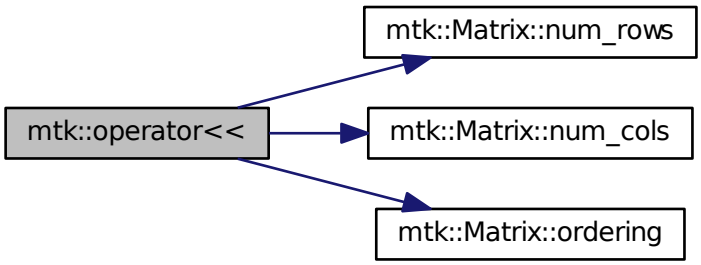
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

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 >= n: find the least squares solution of an overdetermined system, i.e., solve the least squares problem

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

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

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

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

**See also**

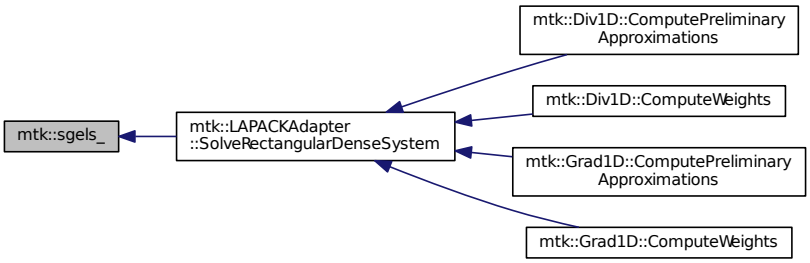
http://www.math.utah.edu/software/lapack/lapack-s/sgels.html

**Parameters**

| | | |
|---|---|---|
| in | *trans* | Am I giving the transpose of the matrix? |
| in | *m* | The number of rows of the matrix a. m >= 0. |
| in | *n* | The number of columns of the matrix a. n >= 0. |
| in | *nrhs* | The number of right-hand sides. |
| in,out | *a* | On entry, the m-by-n matrix a. |
| in | *lda* | The leading dimension of a. lda >= max(1,m). |

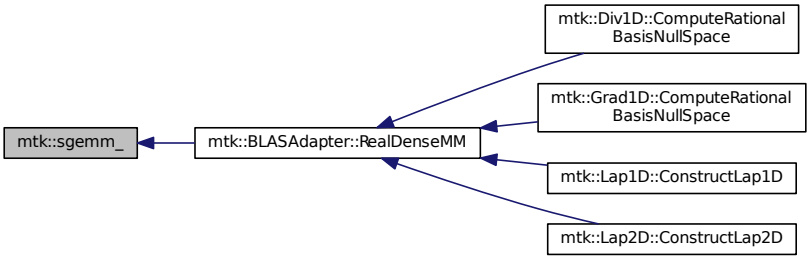
| | | |
|---|---|---|
| in,out | *b* | On entry, matrix b of right-hand side vectors. |
| in | *ldb* | The leading dimension of b. ldb >= max(1,m,n). |
| in,out | *work* | On exit, if info = 0, work(1) is optimal lwork. |
| in,out | *lwork* | The dimension of the array work. |
| in,out | *info* | If info = 0, then successful exit. |

Here is the caller graph for this function:



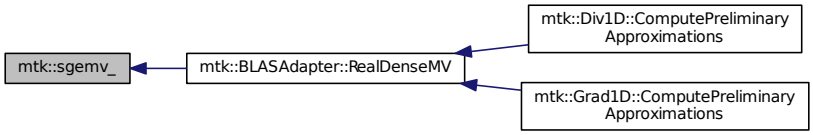

15.1.1.10 **void mtk::sgemm_ ( char * *transa,* char * *transb,* int * *m,* int * *n,* int * *k,* double * *alpha,* double * *a,* int * *lda,* double * *b,* aamm int * *ldb,* double * *beta,* double * *c,* int * *ldc* )**

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) . . . H(k)
```

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

**See also**

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

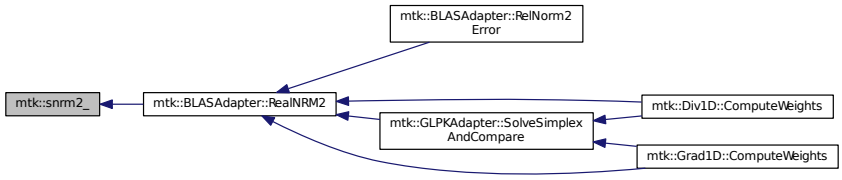
**Parameters**

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

15.1.1.13 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 C * Q TRANS = 'T': Q**T * C C * Q**T
where Q is a real orthogonal matrix defined as the product of k elementary reflectors

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

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

**See also**

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

**Parameters**

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

| | | |
|---|---|---|
| in,out | *info* | info = 0: successful exit. |

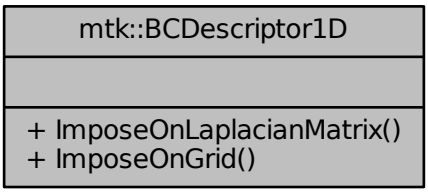
# Chapter 16

# Class Documentation

## 16.1 mtk::BCDescriptor1D Class Reference

`#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

Definition at line 68 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**

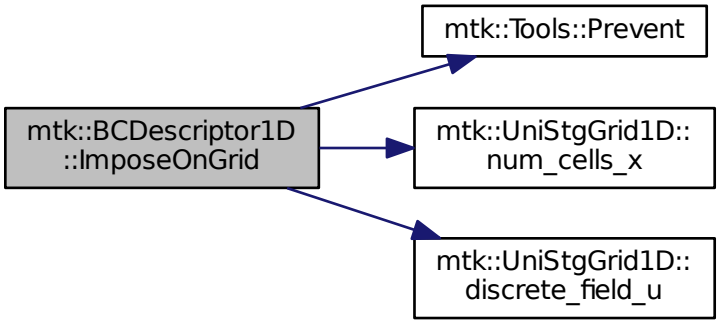
| | | |
|---|---|---|
| in,out | *grid* | Input grid. |
| in | *west* | Array of values for the west boundary. |
| in | *east* | Array of values for the east boundary. |

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**

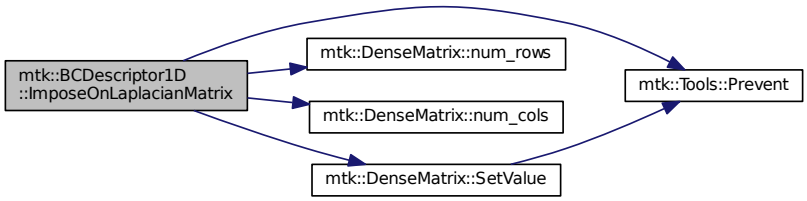
| | | |
|---|---|---|
| in,out | *matrix* | Input operator. |
| in | *west* | Array of values for the west boundary. |
| in | *east* | Array of values for the east boundary. |

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:



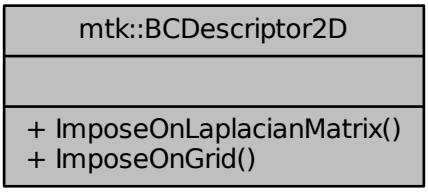

The documentation for this class was generated from the following files:

- include/mtk_bc_descriptor_1d.h
- src/mtk_bc_descriptor_1d.cc

## 16.2 mtk::BCDescriptor2D Class Reference

`#include <mtk_bc_descriptor_2d.h>`

Collaboration diagram for mtk::BCDescriptor2D:




### Static Public Member Functions

- static void ImposeOnLaplacianMatrix (DenseMatrix &matrix, Real(∗west)(int ii, int jj), Real(∗east)(int ii, int jj), Real(∗south)(int ii, int jj), Real(∗north)(int ii, int jj))

  *Enforces the condition on the operator represented as matrix.*
- static void ImposeOnGrid (UniStgGrid2D &grid, Real(∗west)(Real xx, Real yy), Real(∗east)(Real xx, Real yy), Real(∗south)(Real xx, Real yy), Real(∗north)(Real xx, Real yy))

  *Enforces the condition on the grid.*

### 16.2.1 Detailed Description

Definition at line 66 of file mtk_bc_descriptor_2d.h.

### 16.2.2 Member Function Documentation

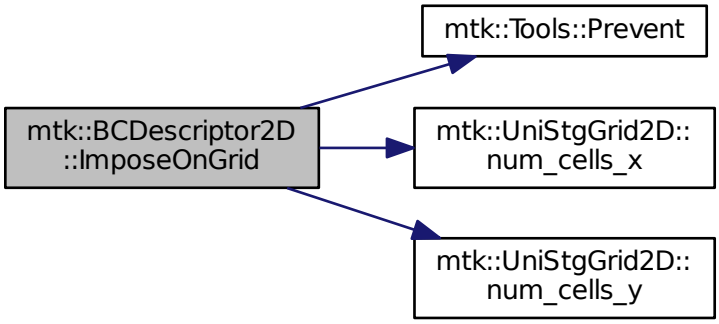
#### 16.2.2.1 void mtk::BCDescriptor2D::ImposeOnGrid ( UniStgGrid2D & *grid*, Real(∗)(Real xx, Real yy) *west*, Real(∗)(Real xx, Real yy) *east*, Real(∗)(Real xx, Real yy) *south*, Real(∗)(Real xx, Real yy) *north* ) [static]

**Parameters**

| in,out | | |
|---|---|---|
| in,out | *matrix* | Input operator. |
| in | *west* | Pointer to function returning west coefficient at (xx,yy). |
| in | *east* | Pointer to function returning east coefficient at (xx,yy). |
| in | *south* | Pointer to function returning south coefficient at (xx,yy). |
| in | *north* | Pointer to function returning north coefficient at (xx,yy). |

Definition at line 79 of file mtk_bc_descriptor_2d.cc.

Here is the call graph for this function:



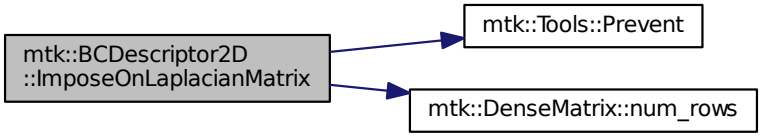

#### 16.2.2.2 void mtk::BCDescriptor2D::ImposeOnLaplacianMatrix ( mtk::DenseMatrix & *matrix*, mtk::Real(∗)(int ii, int jj) *west*, mtk::Real(∗)(int ii, int jj) *east*, mtk::Real(∗)(int ii, int jj) *south*, mtk::Real(∗)(int ii, int jj) *north* ) [static]

**Parameters**

| in,out | | |
|---|---|---|
| in,out | *matrix* | Input operator. |
| in | *west* | Pointer to function returning west coefficient at (ii,jj). |
| in | *east* | Pointer to function returning east coefficient at (ii,jj). |
| in | *south* | Pointer to function returning south coefficient at (ii,jj). |
| in | *north* | Pointer to function returning north coefficient at (ii,jj). |

Definition at line 61 of file mtk_bc_descriptor_2d.cc.

Here is the call graph for this function:




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

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

*Computes the relative norm-2 of the error.*

- static void RealDenseMV (Real &alpha, DenseMatrix &aa, Real *xx, Real &beta, Real *yy)

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

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

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

### 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

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

**Parameters**

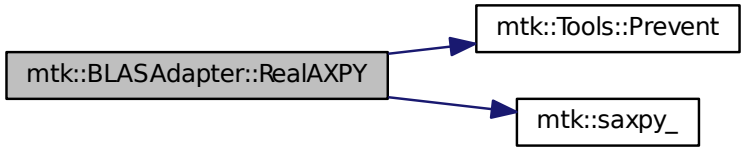
| | | |
|---|---|---|
| in | *alpha* | Scalar of the first array. |
| in | *xx* | First array. |
| in | *yy* | Second array. |
| in | *in_length* | Lengths of the given arrays. |

**Returns**

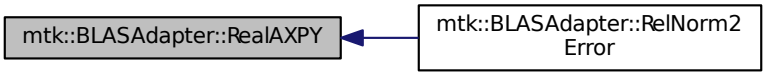
Norm-2 of the given array.

Definition at line 339 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




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

Performs:

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

**Parameters**

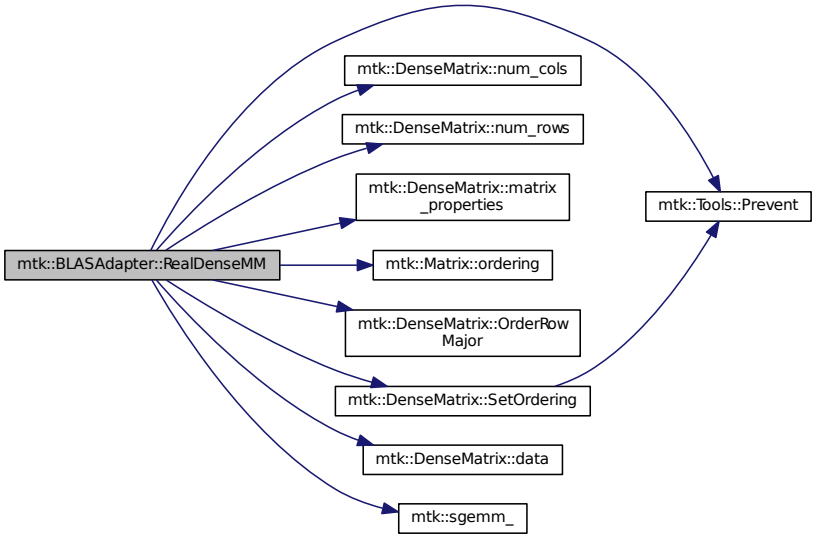
| | | |
|---|---|---|
| in | *aa* | First matrix. |
| in | *bb* | Second matrix. |

**See also**

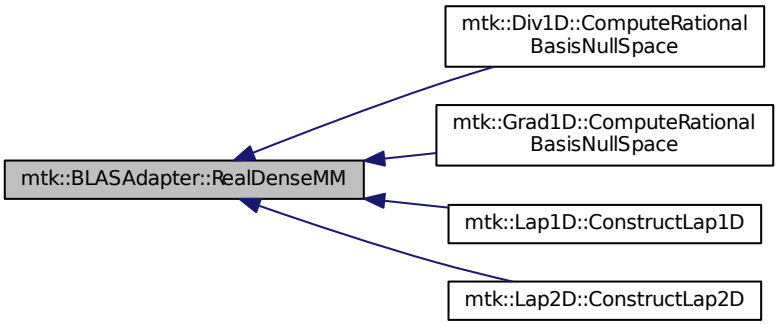
http://ejspeiro.github.io/Netlib-and-CPP/

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**

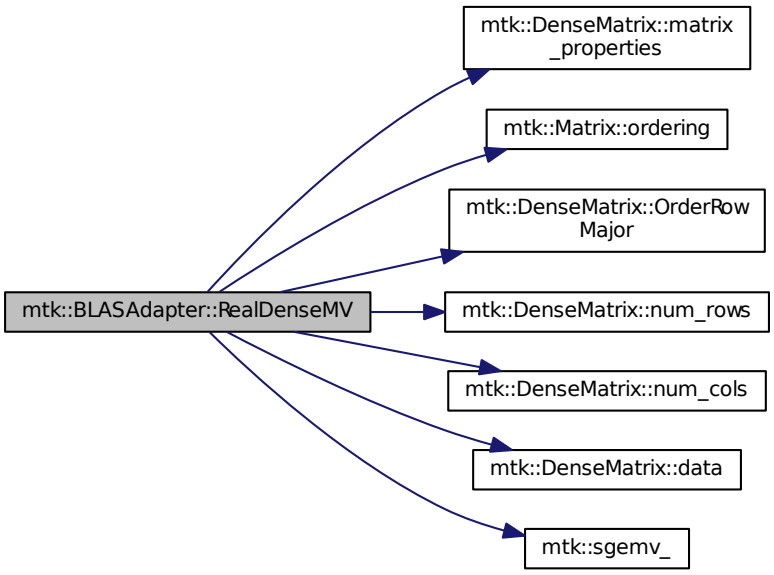
| | | |
|---|---|---|
| in | *alpha* | First scalar. |
| in | *aa* | Given matrix. |
| in | *xx* | First vector. |
| in | *beta* | Second scalar. |
| in,out | *yy* | Second vector (output). |

**See also**

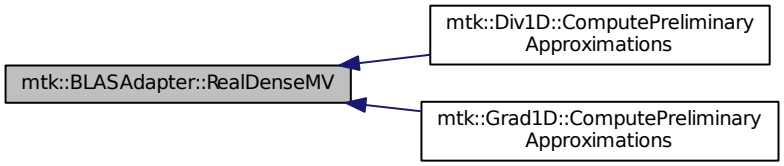
http://ejspeiro.github.io/Netlib-and-CPP/

Definition at line 378 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:




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

**Parameters**

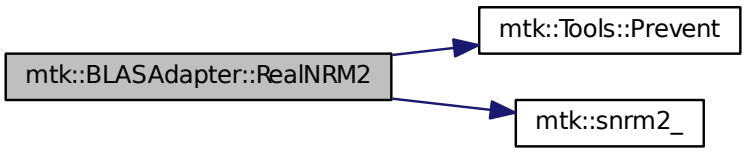
| | | |
|---|---|---|
| in | *in* | Input array. |
| in | *in_length* | Length of the array. |

**Returns**

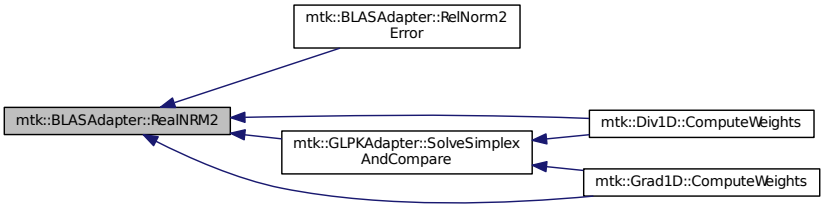
Norm-2 of the given array.

Definition at line 324 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



#### 16.3.2.5 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**

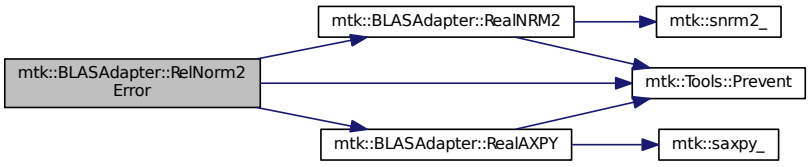
| | | |
|---|---|---|
| in | *known* | Array containing the computed solution. |
| in | *computed* | Array containing the known solution (ref. solution). |

**Returns**

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

Definition at line 358 of file mtk_blas_adapter.cc.

Here is the call graph for this function:




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

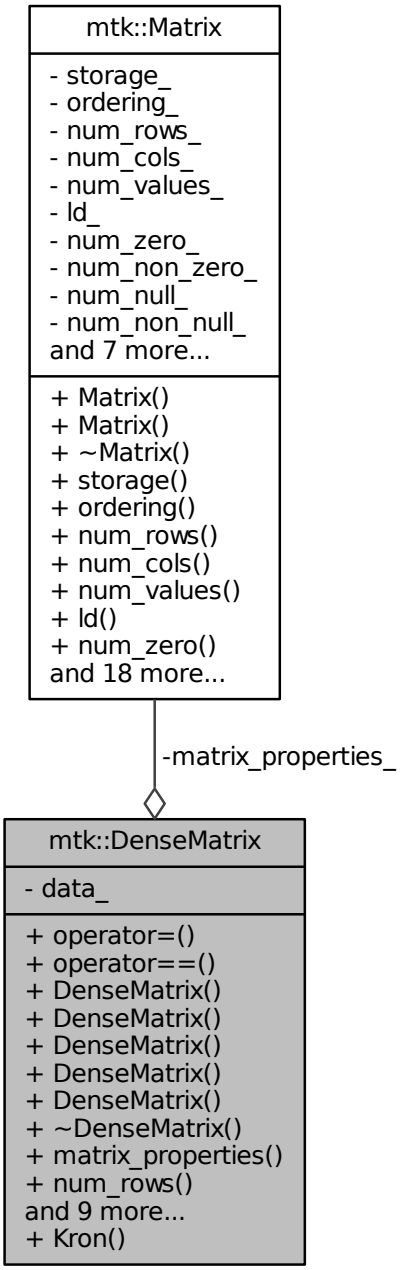
- include/mtk_blas_adapter.h
- src/mtk_blas_adapter.cc

## 16.4 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 *gen, const int &gen_length, const int &pro_length, const bool &transpose)

  *Construct a dense Vandermonde matrix.*

- ~DenseMatrix ()

  *Destructor.*

- Matrix matrix_properties () const

  *Provides access to the matrix data.*

- int num_rows () const

  *Gets the number of rows.*

- int num_cols () const

  *Gets the number of columns.*

- Real * data () const

  *Provides access to the matrix value array.*

- void SetOrdering (mtk::MatrixOrdering oo)

  *Sets the ordering of the matrix.*

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

  *Gets a value on the given coordinates.*

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

  *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 (std::string filename)

  *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-intrincated data structure implementing matrices. This is the purpose of this class: to be used for prototypes of new code for small test cases. In every other instance, this should be replaced by the most appropriate sparse matrix.

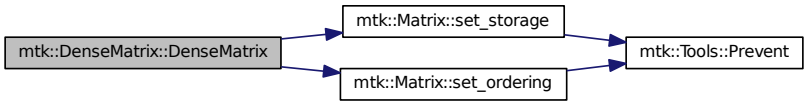
Definition at line 92 of file mtk_dense_matrix.h.

## 16.4.2 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:



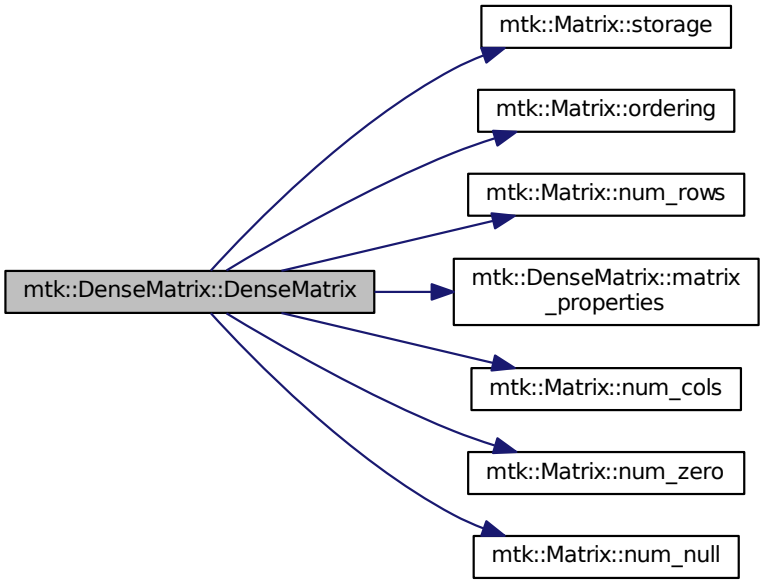

### 16.4.2.2 mtk::DenseMatrix::DenseMatrix ( const DenseMatrix & *in* )

**Parameters**

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

**Exceptions**

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

Definition at line 201 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

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

**Exceptions**

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

Definition at line 223 of file mtk_dense_matrix.cc.

Here is the call graph for this function:


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

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

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

This constructor generates a Vandermonde matrix, as defined above.

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

**Parameters**

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

**Exceptions**

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

Definition at line 264 of file mtk_dense_matrix.cc.

Here is the call graph for this function:


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

Definition at line 312 of file mtk_dense_matrix.cc.

### 16.4.3 Member Function Documentation

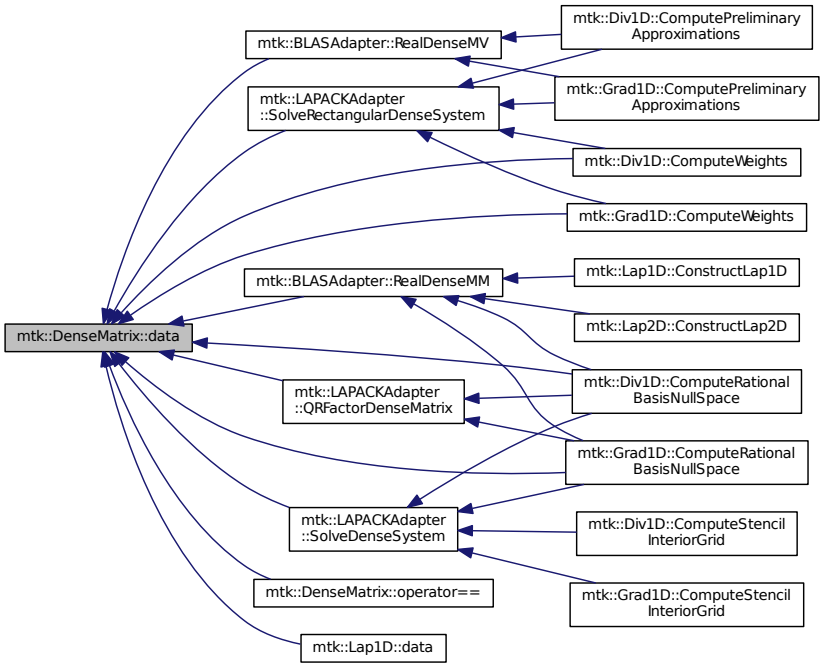
#### 16.4.3.1 mtk::Real * mtk::DenseMatrix::data ( ) const

**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

**Parameters**

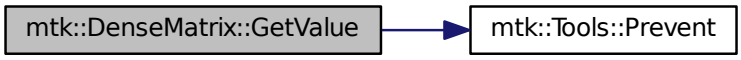
| | | |
|---|---|---|
| in | *row_coord* | Row coordinate. |
| in | *col_coord* | Column coordinate. |

**Returns**

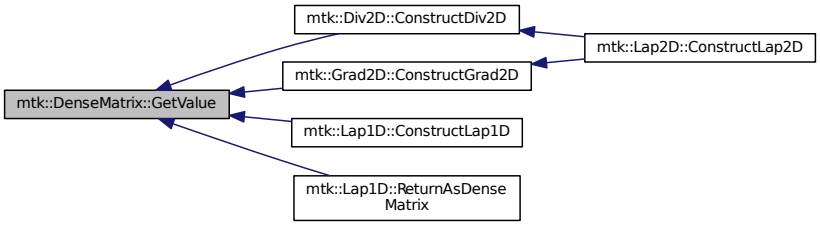
The required value at the specified coordinates.

Definition at line 348 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




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

**Parameters**

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

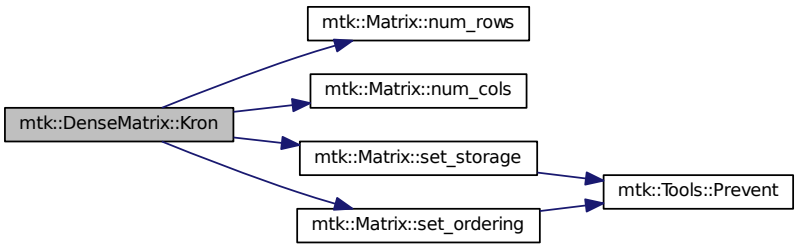
**Exceptions**

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

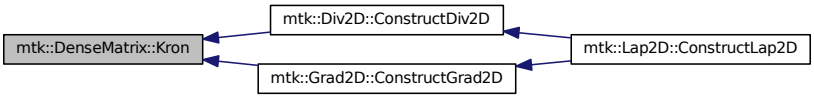
**Todo** Implement Kronecker product using the BLAS.

Definition at line 490 of file mtk_dense_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:



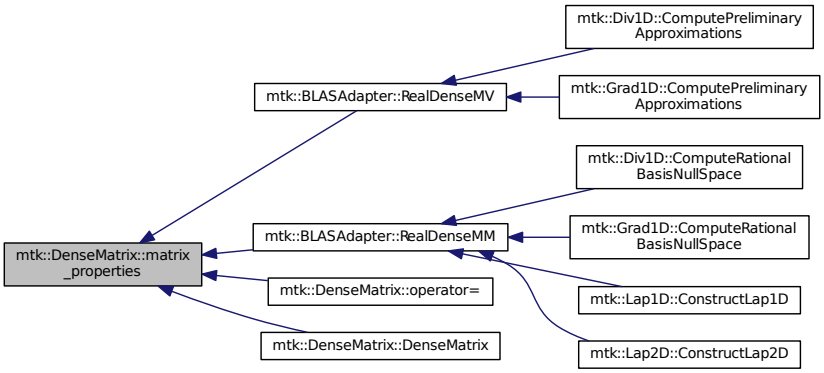

#### 16.4.3.4 mtk::Matrix mtk::DenseMatrix::matrix_properties ( ) const

**Returns**

Pointer to a Matrix.

Definition at line 318 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



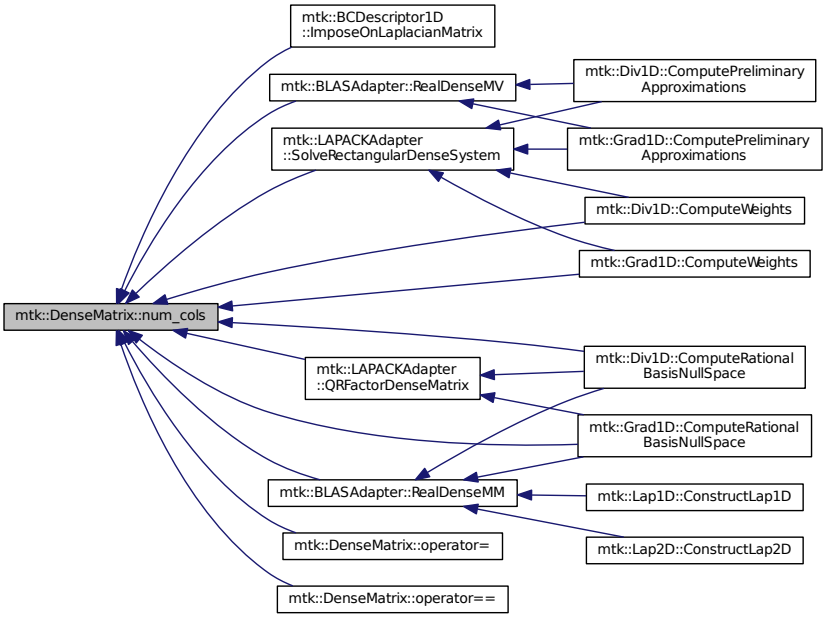
#### 16.4.3.5 int mtk::DenseMatrix::num_cols ( ) const

**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:



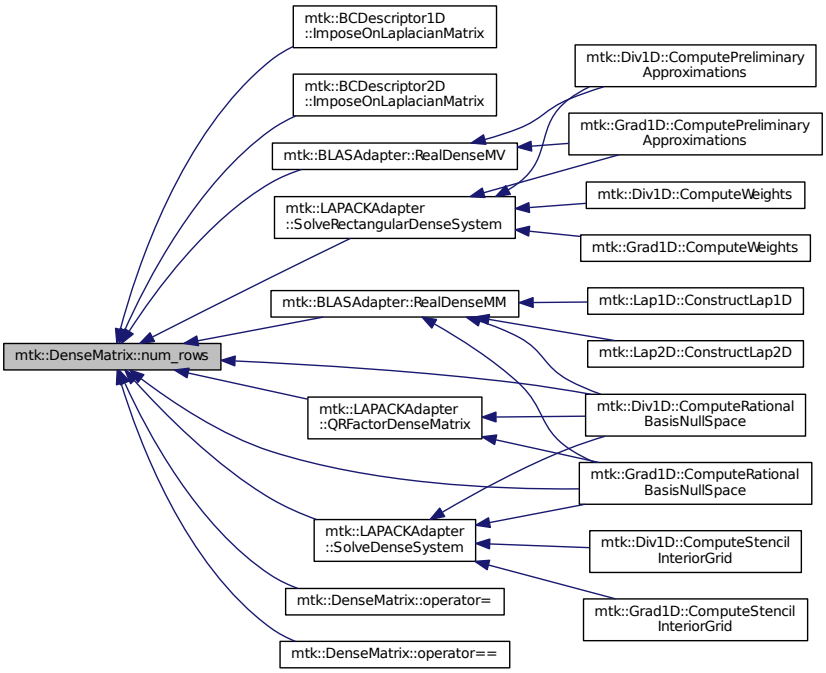

#### 16.4.3.6 int mtk::DenseMatrix::num_rows ( ) const

**Returns**

Number of rows of the matrix.

Definition at line 333 of file mtk_dense_matrix.cc.

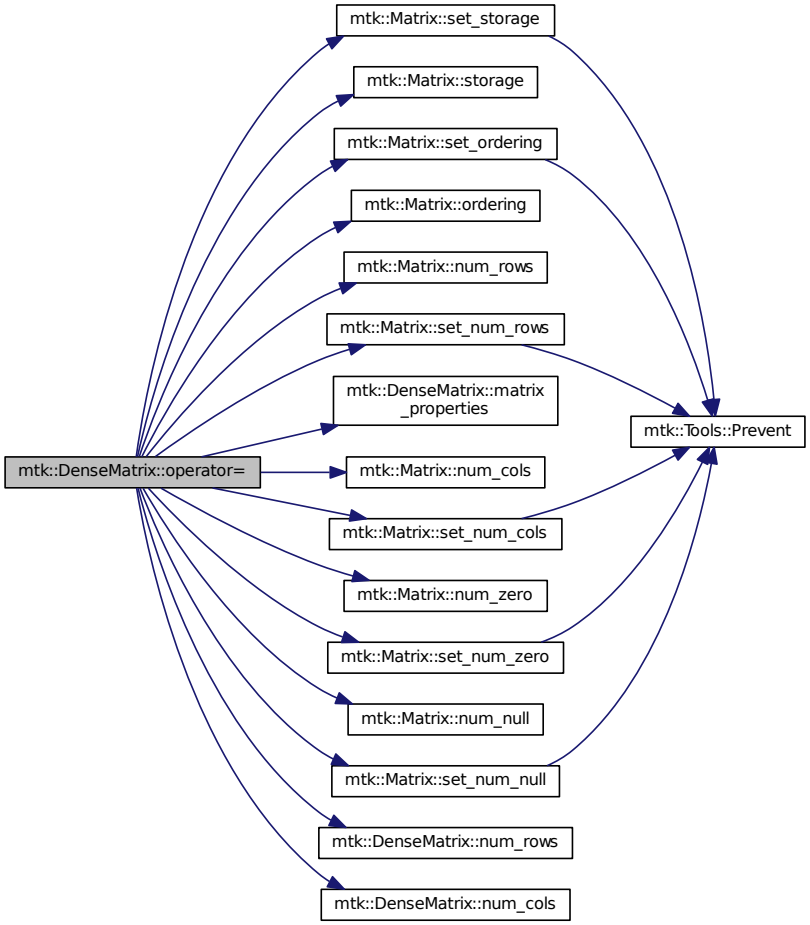
Here is the caller graph for this function:




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

Definition at line 100 of file mtk_dense_matrix.cc.

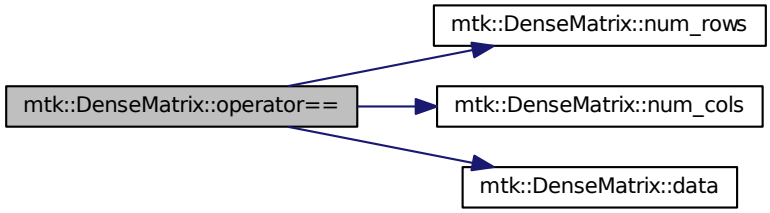
Here is the call graph for this function:




#### 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:

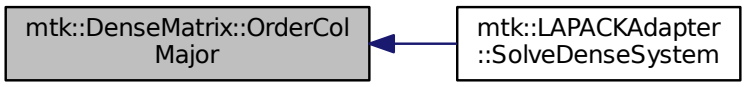



#### 16.4.3.9 void mtk::DenseMatrix::OrderColMajor ( )

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

Definition at line 451 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:

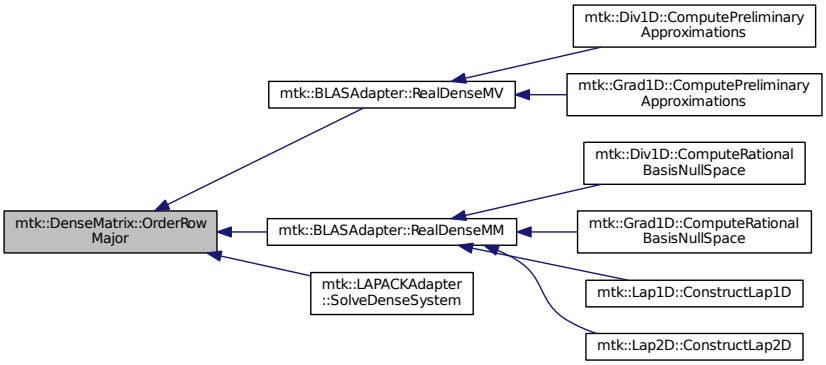



#### 16.4.3.10 void mtk::DenseMatrix::OrderRowMajor ( )

**Todo** Improve this so that no new ammays 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* )

**Parameters**

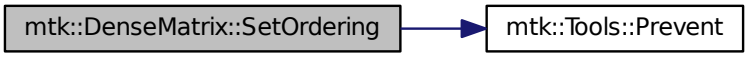
| | | |
|---|---|---|
| in | *oo* | Ordering. |

**Returns**

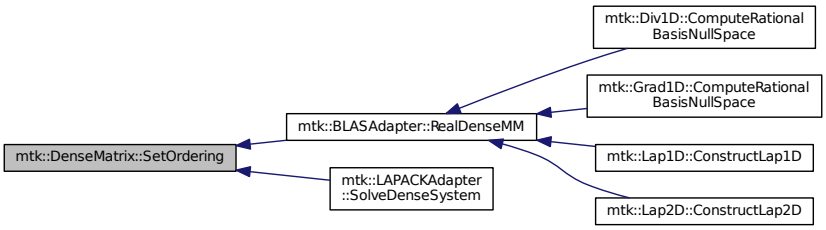
The required value at the specified coordinates.

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:



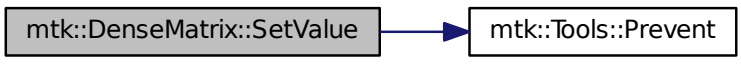

#### 16.4.3.12 void mtk::DenseMatrix::SetValue ( const int & *row_coord,* const int & *col_coord,* const Real & *val* )

**Parameters**

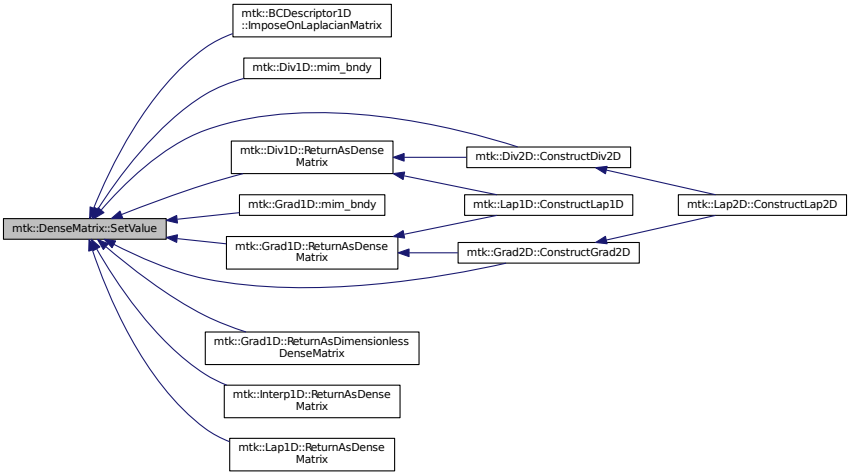
| | | |
|---|---|---|
| in | *row_coord* | Row coordinate. |
| in | *col_coord* | Column coordinate. |
| in | *val* | Row Actual value to be inserted. |

Definition at line 360 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

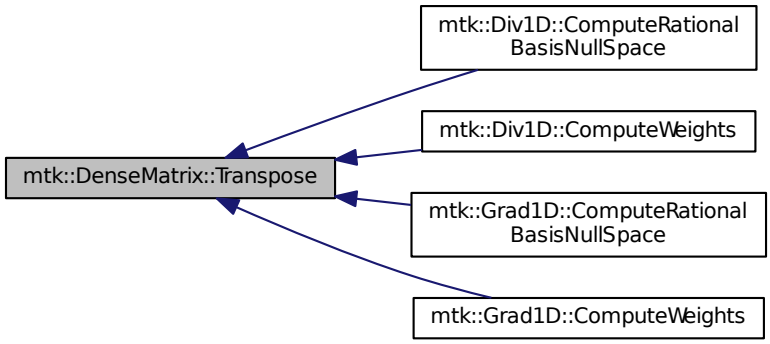



#### 16.4.3.13 void mtk::DenseMatrix::Transpose ( )

**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 ( std::string *filename* )

**Parameters**

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

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Definition at line 531 of file mtk_dense_matrix.cc.

### 16.4.4 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 284 of file mtk_dense_matrix.h.

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

Definition at line 282 of file mtk_dense_matrix.h.

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

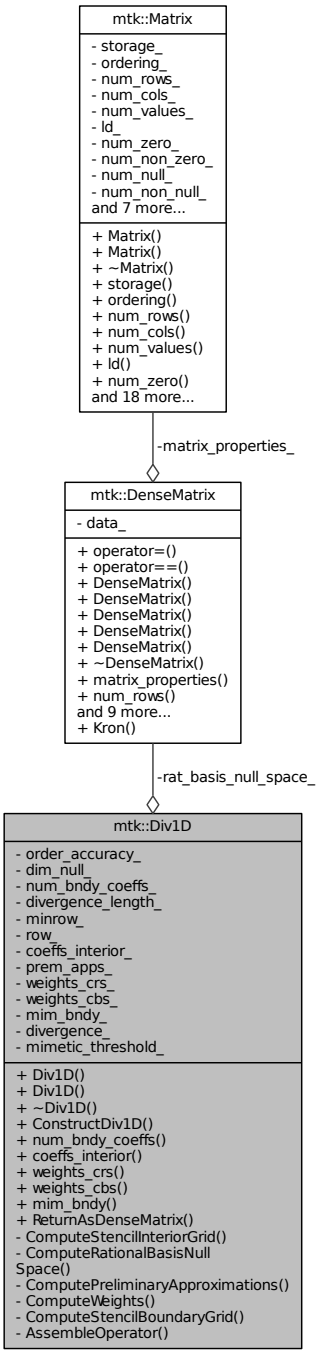
- include/mtk_dense_matrix.h
- src/mtk_dense_matrix.cc

## 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_coeffs () const

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

- Real * coeffs_interior () const

  *Returns coefficients for the interior of the grid.*

- Real * weights_crs (void) const

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

- Real * weights_cbs (void) const

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

- DenseMatrix mim_bndy () const

  *Return collection of mimetic approximations at the boundary.*

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid)

  *Return the operator as a dense matrix.*

## Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  *Stage 1 of the CBS Algorithm.*

- bool ComputeRationalBasisNullSpace (void)

  *Stage 2.1 of the CBS Algorithm.*

- bool ComputePreliminaryApproximations (void)

  *Stage 2.2 of the CBS Algorithm.*

- bool ComputeWeights (void)

  *Stage 2.3 of the CBS Algorithm.*

- bool ComputeStencilBoundaryGrid (void)

  *Stage 2.4 of the CBS Algorithm.*

- bool AssembleOperator (void)

  *Stage 3 of the CBS Algorithm.*

## Private Attributes

- int order_accuracy_

  *Order of numerical accuracy of the operator.*

- int dim_null_

  *Dim. null-space for boundary approximations.*

- int num_bndy_coeffs_

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

- int divergence_length_

  *Length of the output array.*

- int minrow_

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

- int row_

  *Row currently processed by the optimizer.*

- DenseMatrix rat_basis_null_space_

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

- Real * coeffs_interior_

  *Interior stencil.*

- Real * prem_apps_

  *2D array of boundary preliminary approximations.*

- Real * weights_crs_

  *Array containing weights from CRSA.*

- Real * weights_cbs_

  *Array containing weights from CBSA.*

- Real * mim_bndy_

  *Array containing mimetic boundary approximations.*

- Real * divergence_

  *Output array containing the operator and weights.*

- Real mimetic_threshold_

  *< Mimetic threshold.*

## Friends

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

  *Output stream operator for printing.*

### 16.5.1 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**

| | | |
|---|---|---|
| in | *div* | 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 1333 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.

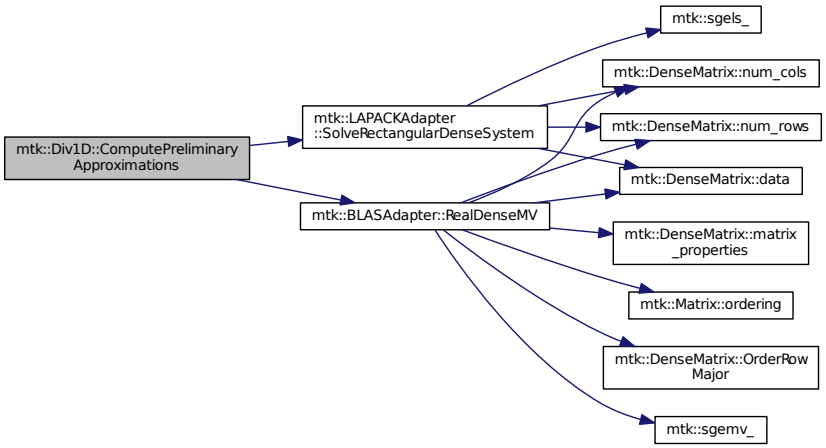
#### 16.5.3.3 bool mtk::Div1D::ComputePreliminaryApproximations ( void ) [private]

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 688 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.

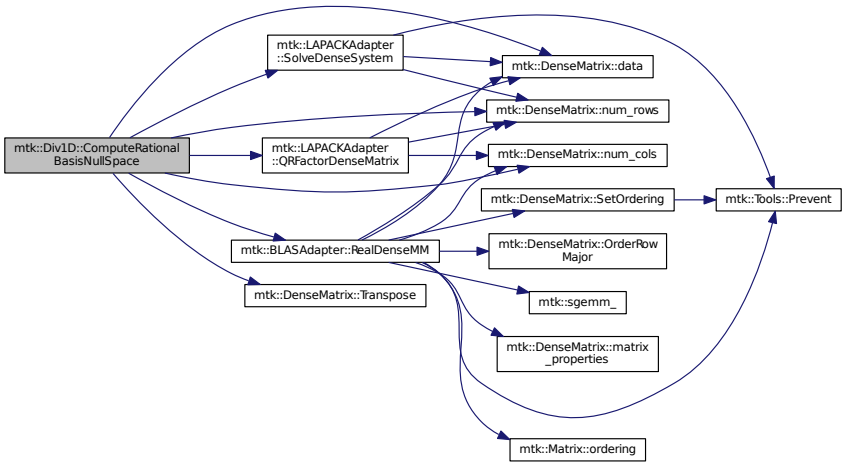
3. QR-factorize the Vandermonde matrix.

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

5. Scale null-space to make it rational.

Definition at line 512 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 1234 of file mtk_div_1d.cc.

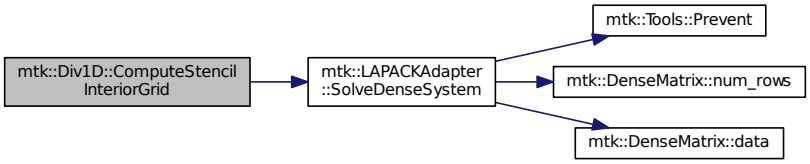
#### 16.5.3.6 bool mtk::Div1D::ComputeStencilInteriorGrid ( void ) [private]

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 413 of file mtk_div_1d.cc.

Here is the call graph for this function:



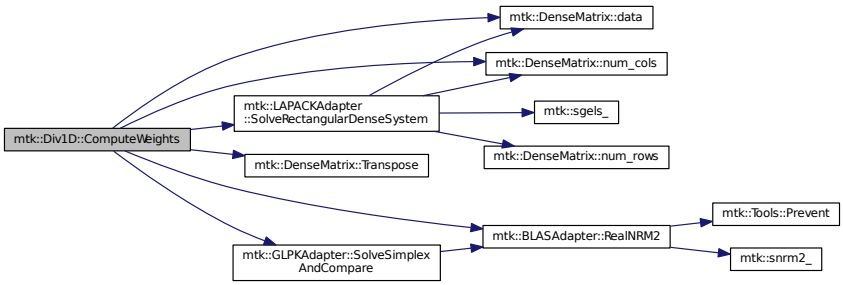

#### 16.5.3.7 bool mtk::Div1D::ComputeWeights ( void ) [private]

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

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

Definition at line 908 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 )

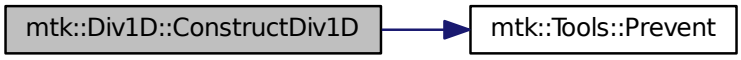
**Returns**

Success of the construction.

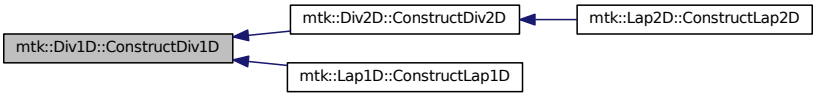
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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



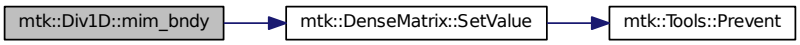

#### 16.5.3.9 mtk::DenseMatrix mtk::Div1D::mim_bndy ( ) const

**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* )

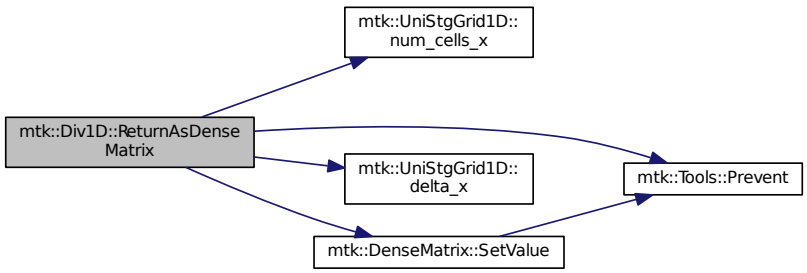
**Returns**

The operator as a dense matrix.

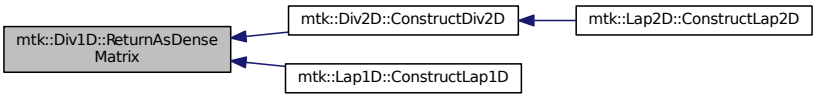
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

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:

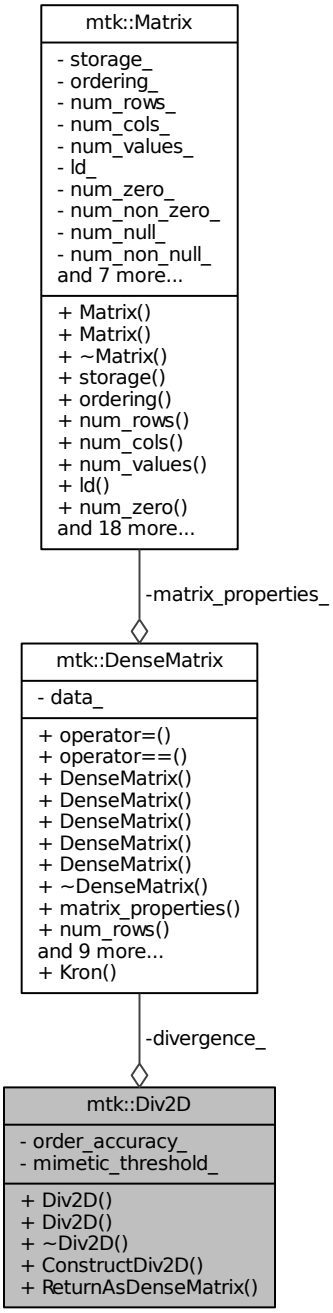
- include/mtk_div_1d.h

- src/mtk_div_1d.cc

## 16.6 mtk::Div2D Class Reference

```
#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 ()

  *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

Definition at line 66 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**

| | | |
|---|---|---|
| in | *div* | 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

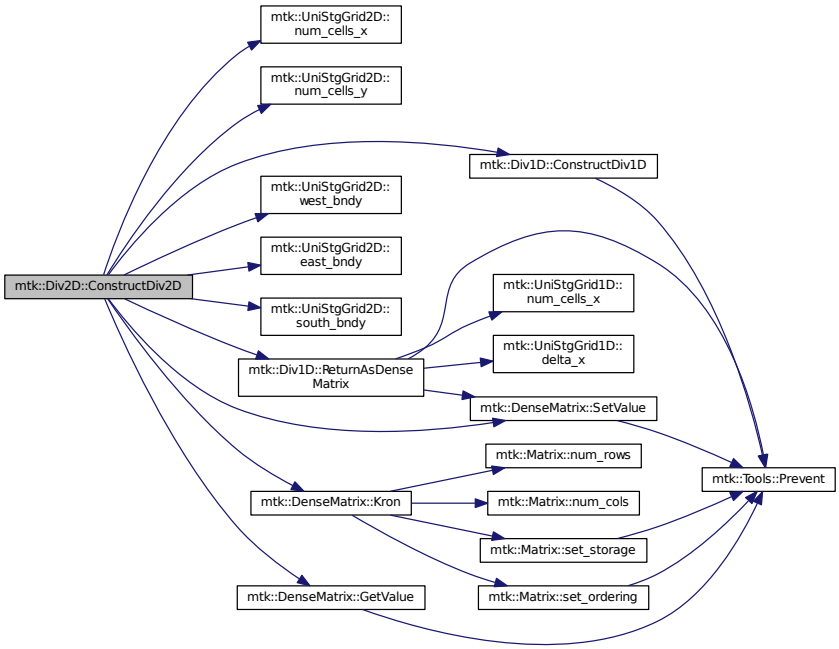
#### 16.6.3.1 bool mtk::Div2D::ConstructDiv2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**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:

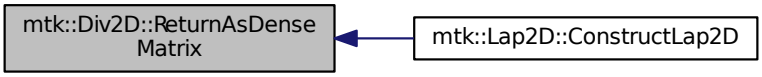

#### 16.6.3.2 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix ( )

**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 98 of file mtk_div_2d.h.

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

Definition at line 102 of file mtk_div_2d.h.

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

Definition at line 100 of file mtk_div_2d.h.

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

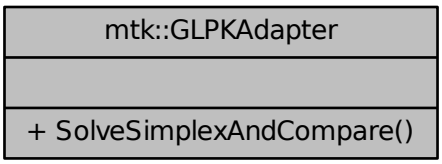
- include/mtk_div_2d.h
- src/mtk_div_2d.cc

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

**Returns**

Relative error computed between attained solution and provided ref.

**Warning**

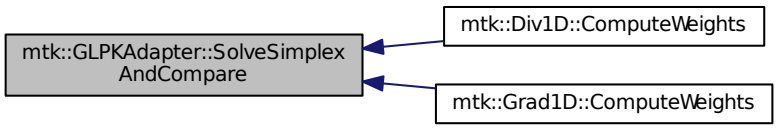
GLPK indexes in [1,n], so we must get the extra space needed.

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

Definition at line 76 of file mtk_glpk_adapter.cc.

Here is the call graph for this function:

Here is the caller graph for this function:




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

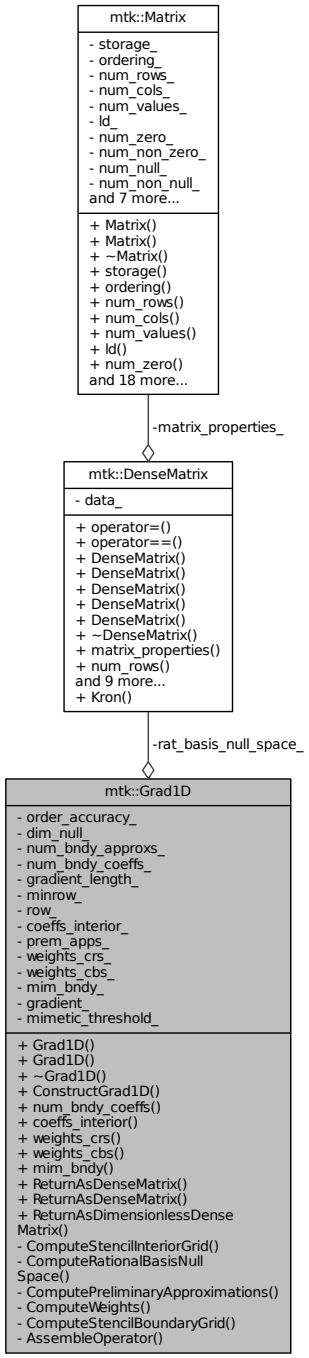
- include/mtk_glpk_adapter.h
- src/mtk_glpk_adapter.cc

## 16.8 mtk::Grad1D Class Reference

Implements a 1D mimetic gradient operator.

`#include <mtk_grad_1d.h>`

Collaboration diagram for mtk::Grad1D:




## Public Member Functions

- Grad1D ()

*Default constructor.*

- Grad1D (const Grad1D &grad)

  *Copy constructor.*

- ~Grad1D ()

  *Destructor.*

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

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

- int num_bndy_coeffs () const

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

- Real * coeffs_interior () const

  *Returns coefficients for the interior of the grid.*

- Real * weights_crs (void) const

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

- Real * weights_cbs (void) const

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

- DenseMatrix mim_bndy () const

  *Return collection of mimetic approximations at the boundary.*

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

  *Returns the operator as a dense matrix.*

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid)

  *Returns the operator as a dense matrix.*

- DenseMatrix ReturnAsDimensionlessDenseMatrix (int num_cells_x)

  *Returns the operator as a dimensionless dense matrix.*

## Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  *Stage 1 of the CBS Algorithm.*

- bool ComputeRationalBasisNullSpace (void)

  *Stage 2.1 of the CBS Algorithm.*

- bool ComputePreliminaryApproximations (void)

  *Stage 2.2 of the CBS Algorithm.*

- bool ComputeWeights (void)

  *Stage 2.3 of the CBS Algorithm.*

- bool ComputeStencilBoundaryGrid (void)

  *Stage 2.4 of the CBS Algorithm.*

- bool AssembleOperator (void)

  *Stage 3 of the CBS Algorithm.*

## Private Attributes

- int order_accuracy_

  *Order of numerical accuracy of the operator.*

- int dim_null_

  *Dim. null-space for boundary approximations.*

- int num_bndy_approxs_

*Req. approximations at and near the boundary.*

- int num_bndy_coeffs_

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

- int gradient_length_

  *Length of the output array.*

- int minrow_

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

- int row_

  *Row currently processed by the optimizer.*

- DenseMatrix rat_basis_null_space_

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

- Real * coeffs_interior_

  *Interior stencil.*

- Real * prem_apps_

  *2D array of boundary preliminary approximations.*

- Real * weights_crs_

  *Array containing weights from CRSA.*

- Real * weights_cbs_

  *Array containing weights from CBSA.*

- Real * mim_bndy_

  *Array containing mimetic boundary approximations.*

- Real * gradient_

  *Output array containing the operator and weights.*

- Real mimetic_threshold_

  *< Mimetic threshold.*

## Friends

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

  *Output stream operator for printing.*

### 16.8.1 Detailed Description

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

Definition at line 81 of file mtk_grad_1d.h.

### 16.8.2 Constructor & Destructor Documentation

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

Definition at line 129 of file mtk_grad_1d.cc.

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

**Parameters**

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

Definition at line 145 of file mtk_grad_1d.cc.

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

Definition at line 161 of file mtk_grad_1d.cc.

### 16.8.3 Member Function Documentation

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

Construct the output array with the operator and its weights.

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

Definition at line 1497 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.

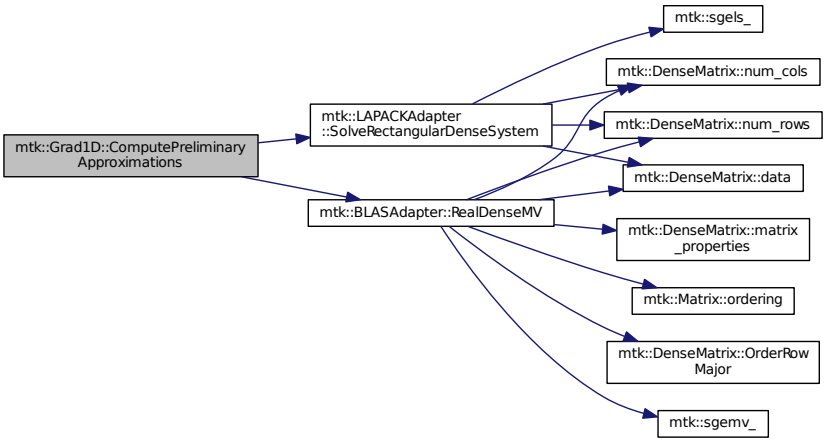
#### 16.8.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations ( void ) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

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

Definition at line 831 of file mtk_grad_1d.cc.

Here is the call graph for this function:




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

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

1. Create generator vector for the first approximation.

2. Create Vandermonde matrix.

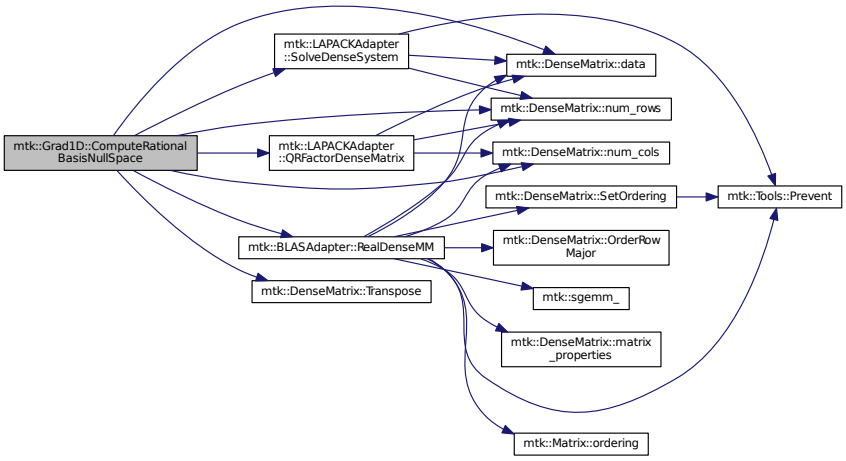
3. QR-factorize the Vandermonde matrix.

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

5. Scale null-space to make it rational.

Definition at line 648 of file mtk_grad_1d.cc.

Here is the call graph for this function:




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

Compute mimetic stencil approximating at boundary.

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

Definition at line 1391 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 552 of file mtk_grad_1d.cc.

Here is the call graph for this function:

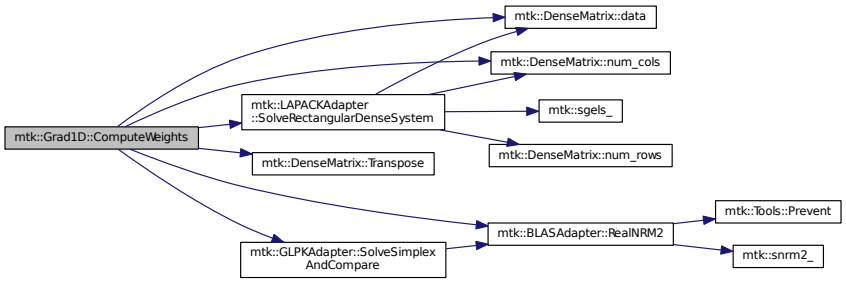

#### 16.8.3.7 bool mtk::Grad1D::ComputeWeights ( void ) [private]

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

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

Definition at line 1051 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**

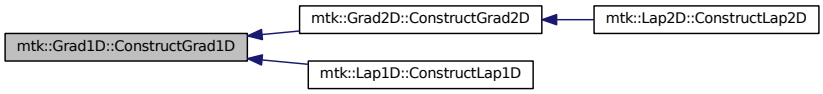
Success of the solution.

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:



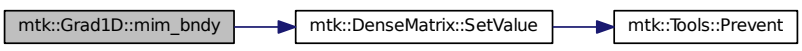

#### 16.8.3.9 mtk::DenseMatrix mtk::Grad1D::mim_bndy ( ) const

**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* )

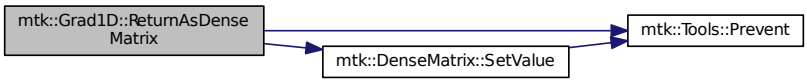
**Returns**

The operator as a dense matrix.

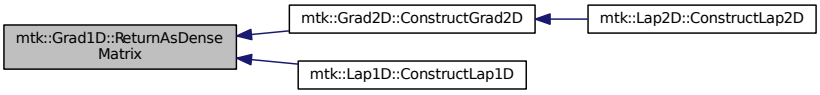
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

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* )

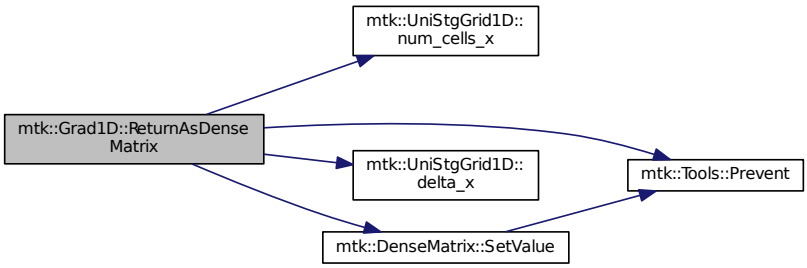
**Returns**

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* )

**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 491 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_approxs_ [private]

Definition at line 209 of file mtk_grad_1d.h.

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

Definition at line 210 of file mtk_grad_1d.h.

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

Definition at line 207 of file mtk_grad_1d.h.

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

Definition at line 218 of file mtk_grad_1d.h.

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

Definition at line 215 of file mtk_grad_1d.h.

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

Definition at line 213 of file mtk_grad_1d.h.

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

Definition at line 220 of file mtk_grad_1d.h.

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

Definition at line 219 of file mtk_grad_1d.h.

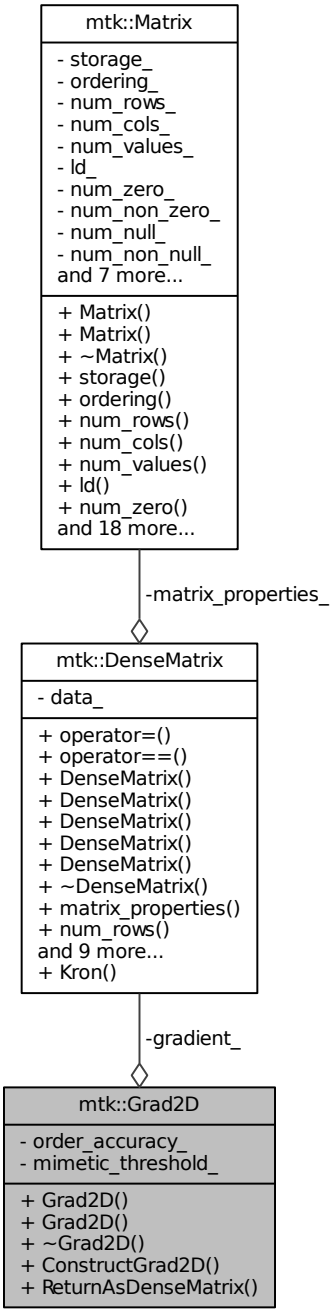
The documentation for this class was generated from the following files:

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

## 16.9 mtk::Grad2D Class Reference

`#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 ()

  *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

Definition at line 66 of file mtk_grad_2d.h.

## 16.9.2 Constructor & Destructor Documentation

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

Definition at line 67 of file mtk_grad_2d.cc.

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

**Parameters**

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

Definition at line 71 of file mtk_grad_2d.cc.

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

Definition at line 75 of file mtk_grad_2d.cc.

## 16.9.3 Member Function Documentation

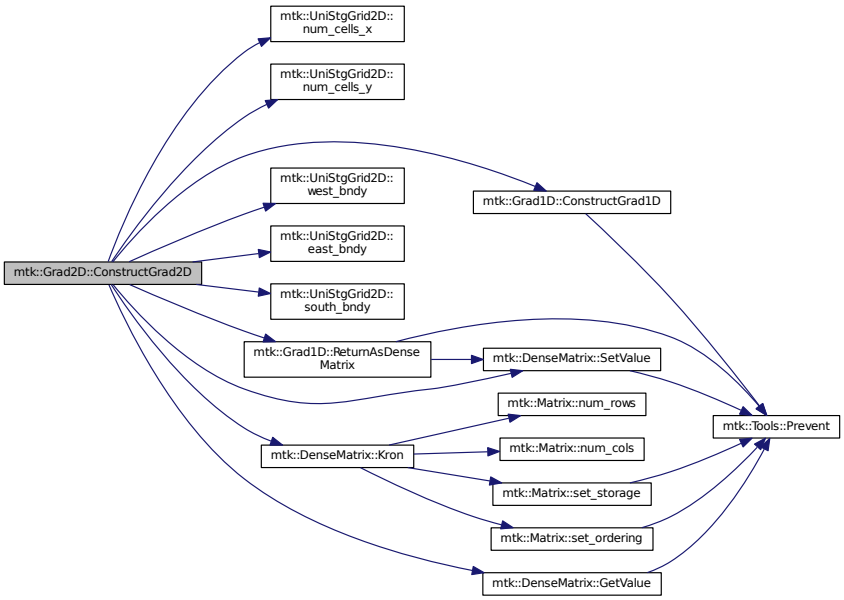
### 16.9.3.1 bool mtk::Grad2D::ConstructGrad2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**Returns**

Success of the construction.

Definition at line 77 of file mtk_grad_2d.cc.

Here is the call graph for this function:




Here is the caller graph for this function:

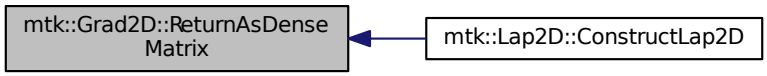

#### 16.9.3.2 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix ( )

**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 98 of file mtk_grad_2d.h.

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

Definition at line 102 of file mtk_grad_2d.h.

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

Definition at line 100 of file mtk_grad_2d.h.

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

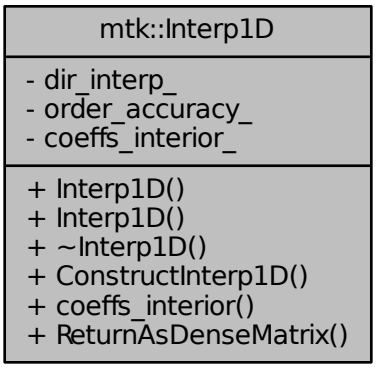
- include/mtk_grad_2d.h
- src/mtk_grad_2d.cc

## 16.10 mtk::Interp1D Class Reference

Implements a 1D interpolation operator.

`#include <mtk_interp_1d.h>`

Collaboration diagram for mtk::Interp1D:




## 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)

  *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**

| | | |
|---|---|---|
| in | *interp* | 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 )

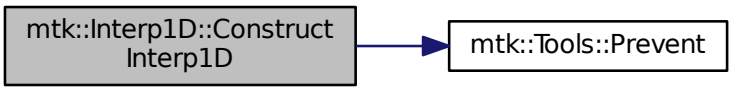
**Returns**

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* )

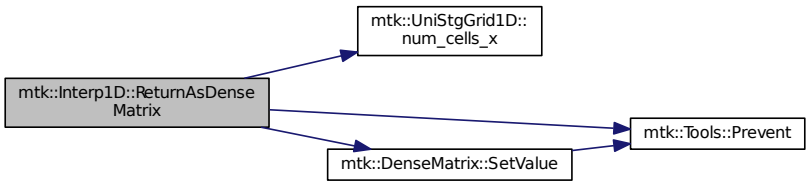
**Returns**

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.

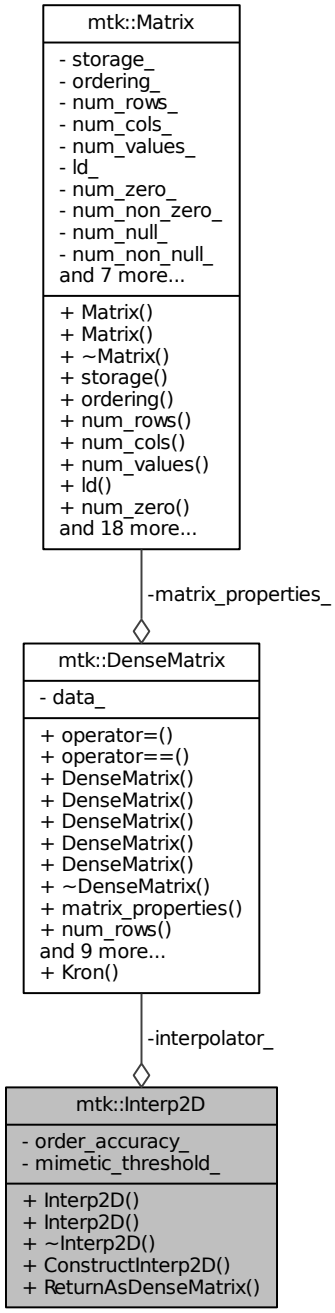
The documentation for this class was generated from the following files:

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

## 16.11 mtk::Interp2D Class Reference

```
#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

Definition at line 67 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**

| | | |
|---|---|---|
| in | *lap* | 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 99 of file mtk_interp_2d.h.

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

Definition at line 103 of file mtk_interp_2d.h.

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

Definition at line 101 of file mtk_interp_2d.h.

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

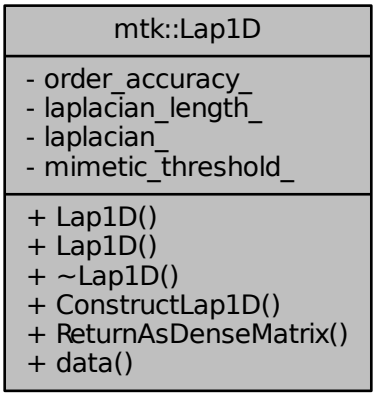
- include/mtk_interp_2d.h

## 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)

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

  *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**

| | | |
|---|---|---|
| in | *lap* | 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.

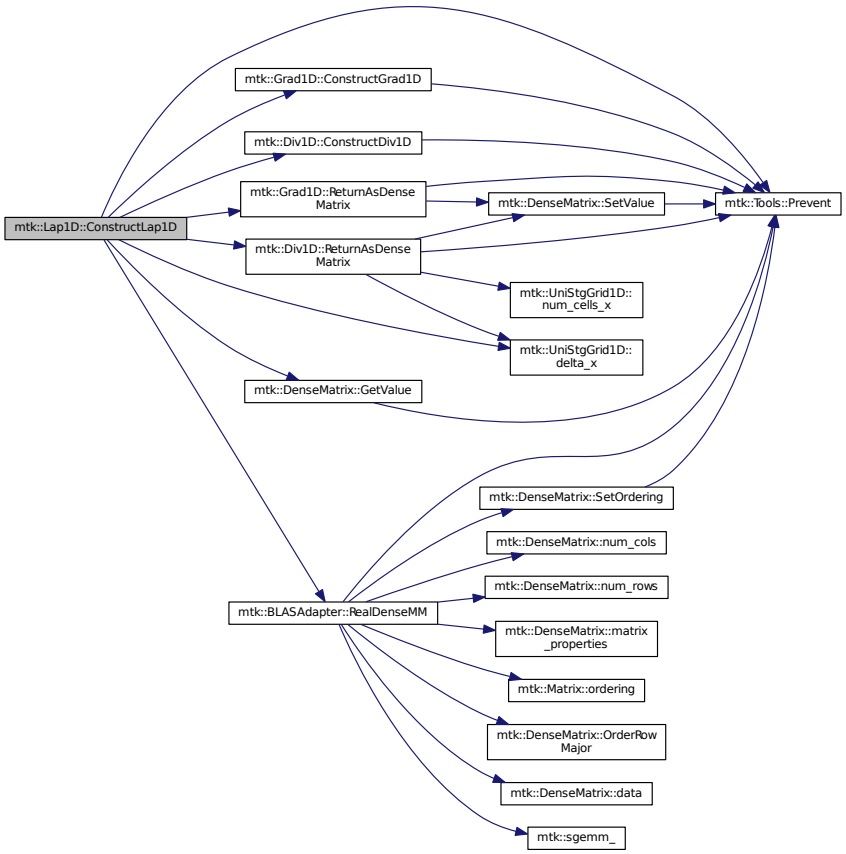
**Warning**

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:



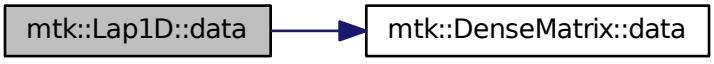

#### 16.12.3.2 mtk::Real * mtk::Lap1D::data ( const UniStgGrid1D & *grid* )

**Returns**

The operator as a dense array.

Definition at line 332 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* )

**Returns**

The operator as a dense matrix.

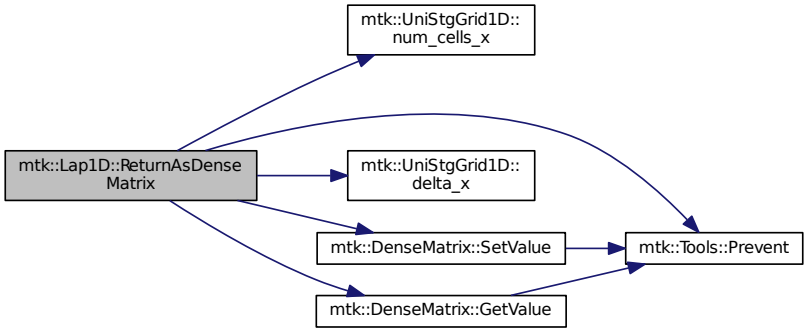
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

**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.

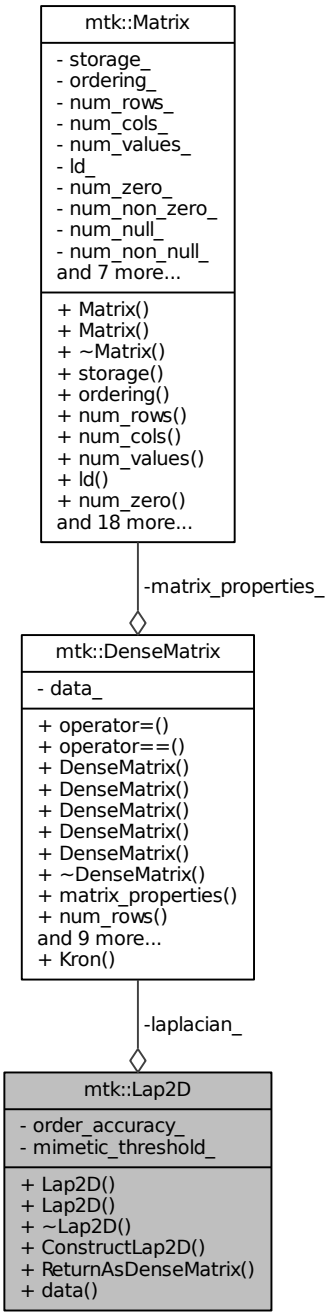
The documentation for this class was generated from the following files:

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

## 16.13 mtk::Lap2D Class Reference

```
#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 ()

  *Return the operator as a dense matrix.*

- mtk::Real * data ()

  *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

Definition at line 66 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**

| | | |
|---|---|---|
| in | *lap* | 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

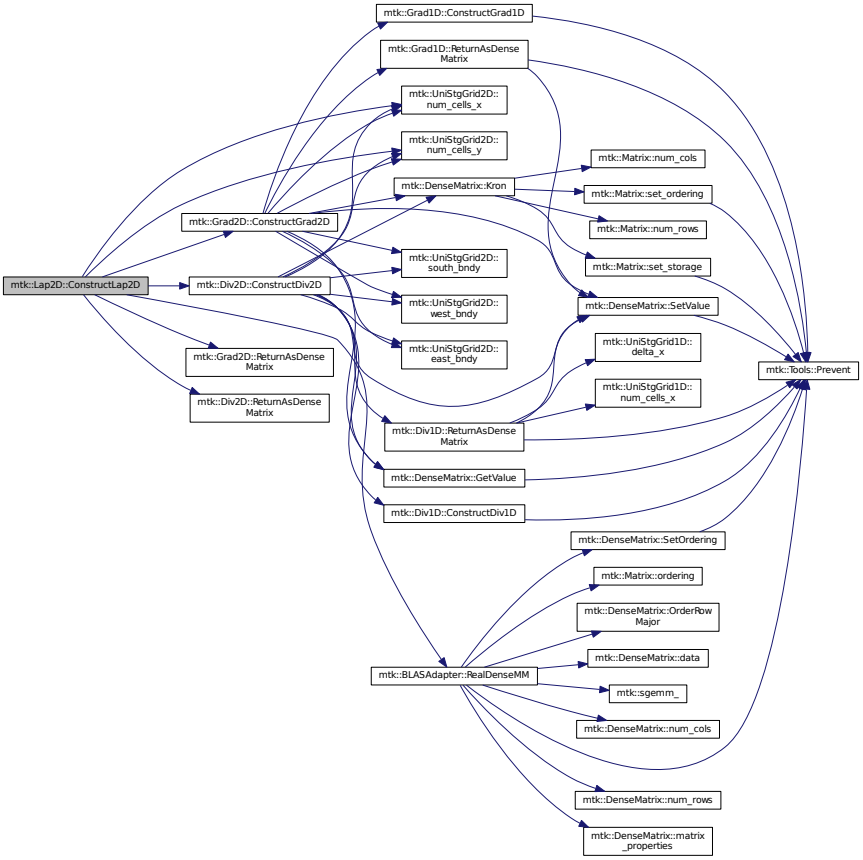
#### 16.13.3.1 bool mtk::Lap2D::ConstructLap2D ( const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold )

**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 ( )

**Returns**

The operator as a dense array.

Definition at line 115 of file mtk_lap_2d.cc.

#### 16.13.3.3 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix ( )

**Returns**

The operator as a dense matrix.

Definition at line 110 of file mtk_lap_2d.cc.

### 16.13.4 Member Data Documentation

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

Definition at line 105 of file mtk_lap_2d.h.

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

Definition at line 109 of file mtk_lap_2d.h.

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

Definition at line 107 of file mtk_lap_2d.h.

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

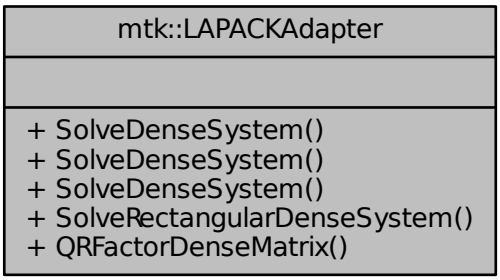
- include/mtk_lap_2d.h
- src/mtk_lap_2d.cc

## 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_ld_)

  *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**

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

**Returns**

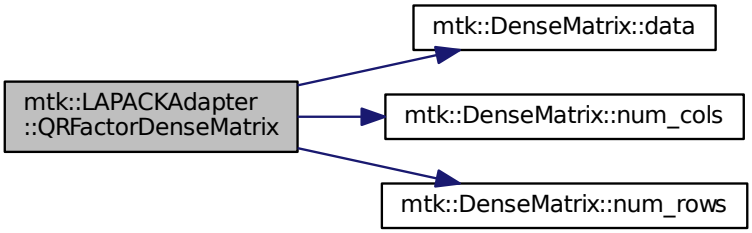
Matrix $\mathbf{Q}$.

**Exceptions**

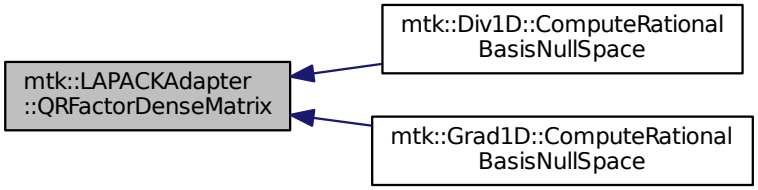
| | |
|---|---|
| *std::bad_alloc* | |

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**

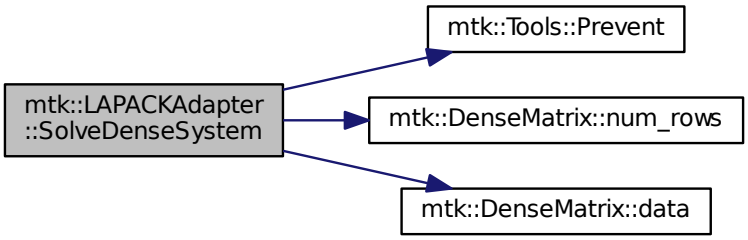
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rhs* | Input right-hand sides vector. |

**Exceptions**

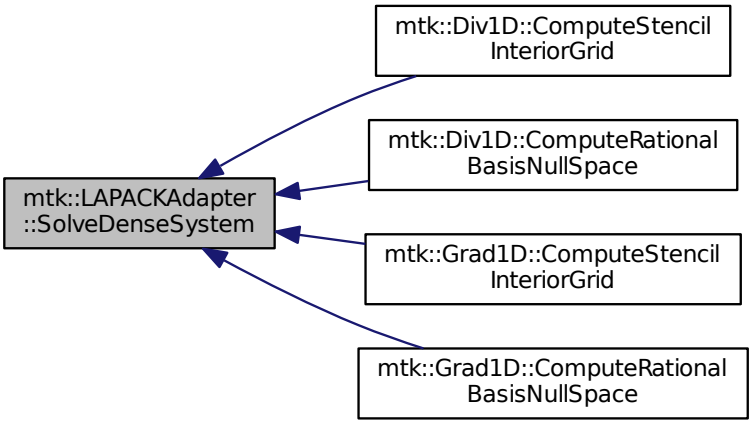
| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 430 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




Here is the caller graph for this function:




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

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

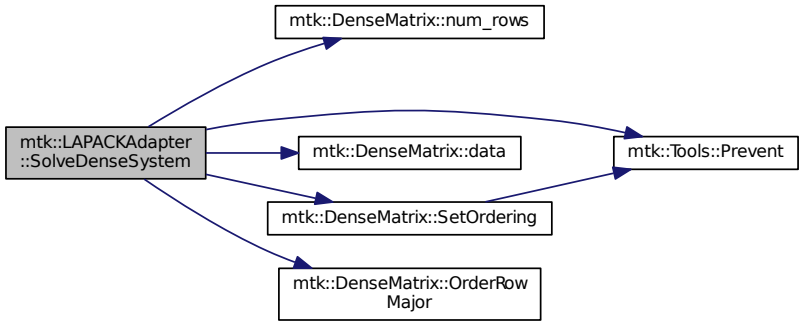
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rr* | Input right-hand sides matrix. |

**Exceptions**

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

Definition at line 465 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




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

Adapts the MTK to LAPACK's dgesv_ routine.

**Parameters**

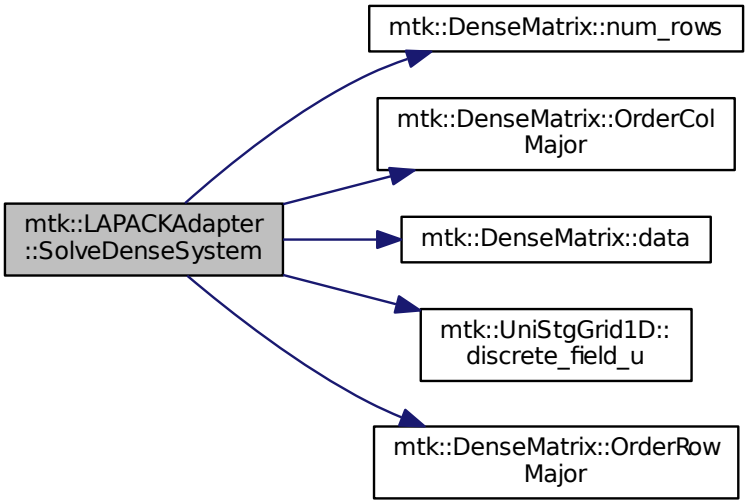
| | | |
|---|---|---|
| in | *matrix* | Input matrix. |
| in | *rr* | Input right-hand side from info on a grid. |

**Exceptions**

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

Definition at line 517 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:




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

Adapts the MTK to LAPACK's routine.

**Parameters**

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

**Returns**

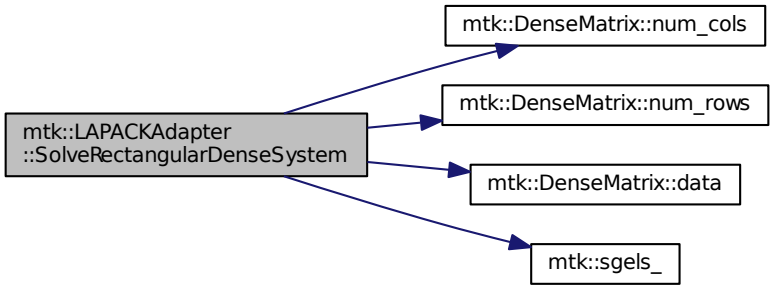
Success of the solution.

**Exceptions**

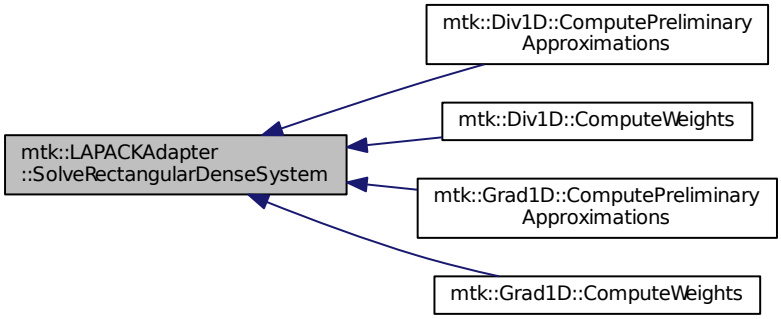
| | |
|---|---|
| *std::bad_alloc* | |

Definition at line 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:

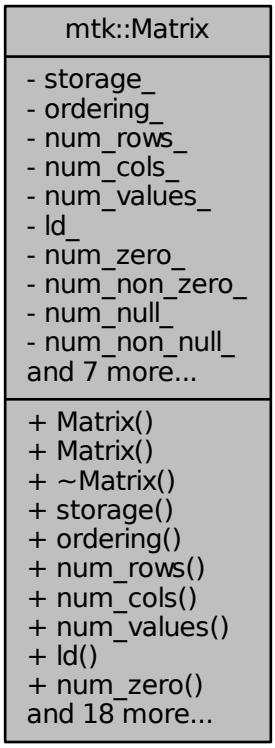
- include/mtk_lapack_adapter.h
- src/mtk_lapack_adapter.cc

## 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:




## Public Member Functions

- Matrix ()

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

  *Copy constructor.*
- ~Matrix ()

  *Destructor.*
- MatrixStorage storage () const

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

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

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

  *Gets the number of rows.*

- int num_values () const

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

  *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**

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

Definition at line 86 of file mtk_matrix.cc.

#### 16.15.2.3 mtk::Matrix::~Matrix ( )

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

**See also**

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

**Returns**

Absolute density of the matrix.

#### 16.15.3.2 mtk::Real mtk::Matrix::abs_sparsity ( ) const

**See also**

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

**Returns**

Absolute sparsity of the matrix.

Definition at line 177 of file mtk_matrix.cc.

#### 16.15.3.3 int mtk::Matrix::bandwidth ( ) const

**Returns**

Bandwidth of the matrix.

Definition at line 167 of file mtk_matrix.cc.

#### 16.15.3.4 void mtk::Matrix::IncreaseNumNull ( )

**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 ( )

**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

**Returns**

Number of lower diagonals.

Definition at line 157 of file mtk_matrix.cc.

#### 16.15.3.7 int mtk::Matrix::ku ( ) const

**Returns**

Number of upper diagonals.

Definition at line 162 of file mtk_matrix.cc.

#### 16.15.3.8 int mtk::Matrix::ld ( ) const

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.

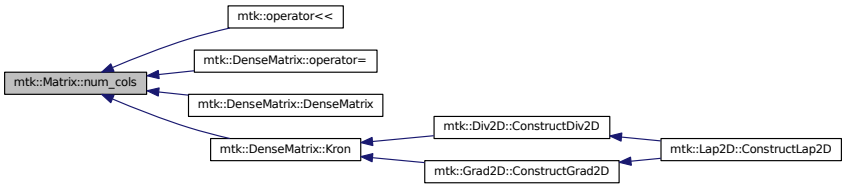
#### 16.15.3.9 int mtk::Matrix::num_cols ( ) const

**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

**See also**

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

**Returns**

Number of non-null values of the matrix.

Definition at line 152 of file mtk_matrix.cc.

#### 16.15.3.11 int mtk::Matrix::num_non_zero ( ) const

**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

**See also**

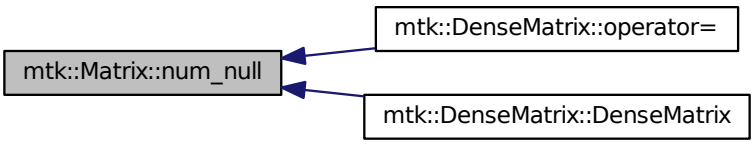
http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

**Returns**

Number of null values of the matrix.

Definition at line 147 of file mtk_matrix.cc.

Here is the caller graph for this function:



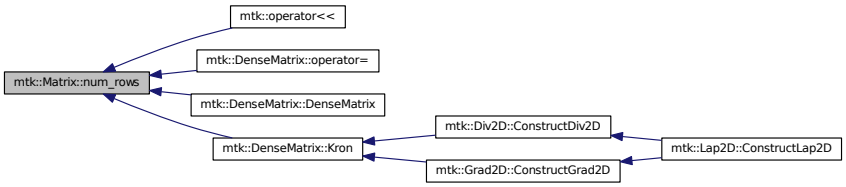

#### 16.15.3.13 int mtk::Matrix::num_rows ( ) const

**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

**Returns**

Number of values of the matrix.

Definition at line 127 of file mtk_matrix.cc.

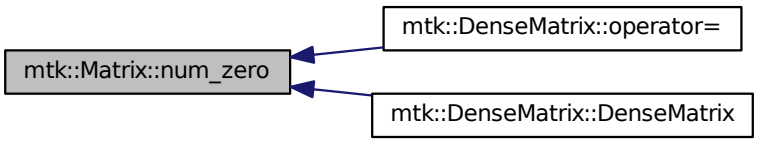
#### 16.15.3.15 int mtk::Matrix::num_zero ( ) const

**Returns**

Number of zeros of the matrix.

Definition at line 137 of file mtk_matrix.cc.

Here is the caller graph for this function:



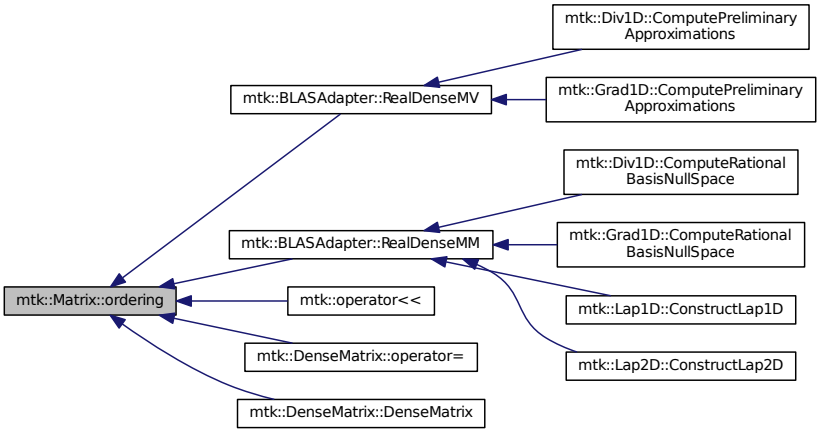

#### 16.15.3.16 mtk::MatrixOrdering mtk::Matrix::ordering ( ) const

**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

**See also**

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

**Returns**

Relative density of the matrix.

Definition at line 172 of file mtk_matrix.cc.

#### 16.15.3.18 mtk::Real mtk::Matrix::rel_sparsity ( ) const

**See also**

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

**Returns**

Relative sparsity of the matrix.

Definition at line 182 of file mtk_matrix.cc.

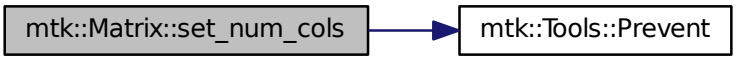
#### 16.15.3.19 void mtk::Matrix::set_num_cols ( int *num_cols* )

**Parameters**

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

Definition at line 224 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.15.3.20 void mtk::Matrix::set_num_null ( int *in* )

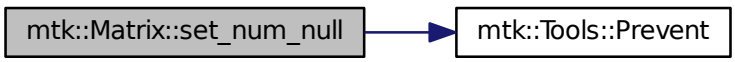
**Parameters**

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

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

Definition at line 250 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

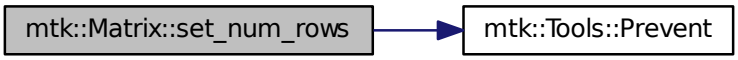

#### 16.15.3.21 void mtk::Matrix::set_num_rows ( int *num_rows* )

**Parameters**

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

Definition at line 212 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.15.3.22 void mtk::Matrix::set_num_zero ( int *in* )

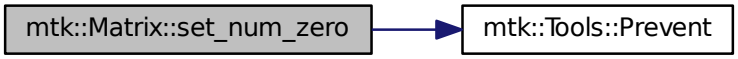
**Parameters**

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

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

Definition at line 236 of file mtk_matrix.cc.

Here is the call graph for this function:




Here is the caller graph for this function:


#### 16.15.3.23 void mtk::Matrix::set_ordering ( const MatrixOrdering & *oo* )

**See also**

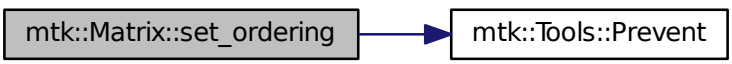
MatrixOrdering

**Parameters**

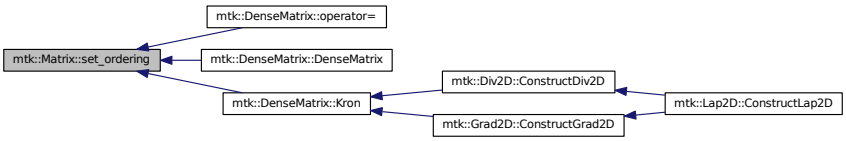
| | | |
|---|---|---|
| in | *oo* | Ordering of the matrix. |

Definition at line 199 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:




#### 16.15.3.24 void mtk::Matrix::set_storage ( const MatrixStorage & *tt* )

**See also**

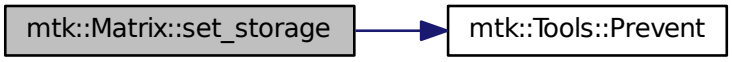
MatrixStorage

**Parameters**

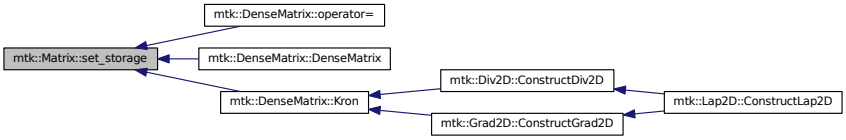
| | | |
|---|---|---|
| in | *tt* | Type of the matrix storage. |

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:



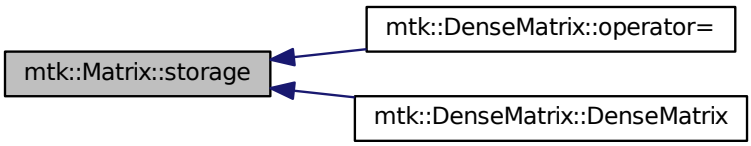

#### 16.15.3.25 mtk::MatrixStorage mtk::Matrix::storage ( ) const

**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:

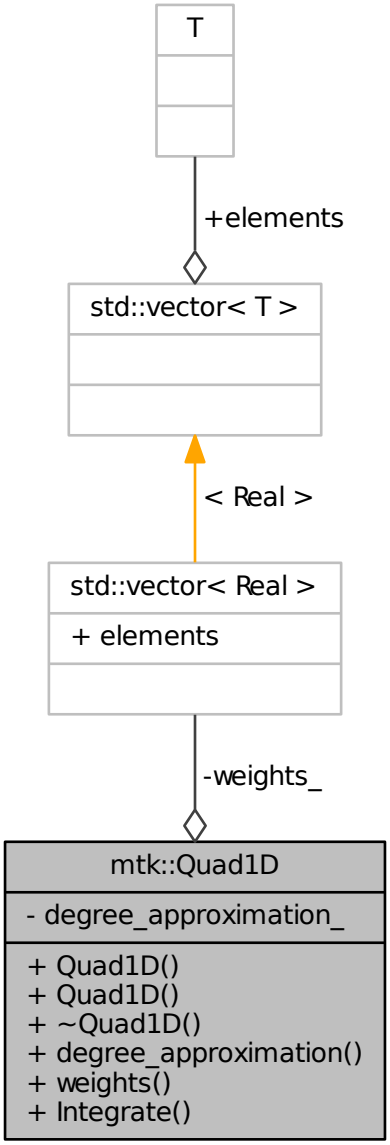
- include/mtk_matrix.h
- src/mtk_matrix.cc

## 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)

  *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**

| | | |
|---|---|---|
| in | *div* | 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* )

**Parameters**

| | | |
|---|---|---|
| in | *Integrand* | Real-valued function to integrate. |
| in | *grid* | 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:

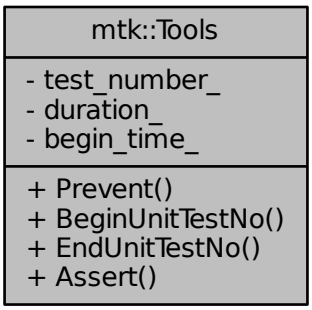
- include/mtk_quad_1d.h

## 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 *fname, int lineno, const char *fxname)

  *Enforces preconditions by preventing their complements from occur.*
- static void BeginUnitTestNo (const int &nn)

  *Begins the execution of a unit test. Starts a timer.*
- static void EndUnitTestNo (const int &nn)

  *Ends the execution of a unit test. Stops and reports wall-clock time.*
- static void Assert (const bool condition)

  *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 74 of file mtk_tools.h.

## 16.17.2 Member Function Documentation

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

**Parameters**

| | | |
|---|---|---|
| in | *condition* | Condition to be asserted. |

Definition at line 114 of file mtk_tools.cc.

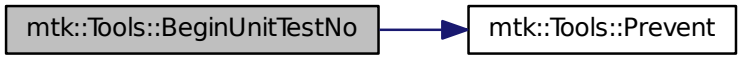
#### 16.17.2.2 void mtk::Tools::BeginUnitTestNo ( const int & *nn* ) [static]

**Parameters**

| | | |
|---|---|---|
| in | *nn* | Number of the test. |

Definition at line 91 of file mtk_tools.cc.

Here is the call graph for this function:



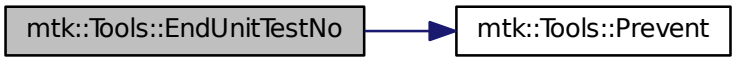

#### 16.17.2.3 void mtk::Tools::EndUnitTestNo ( const int & *nn* ) [static]

**Parameters**

| | | |
|---|---|---|
| in | *nn* | 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 * *fname*, int *lineno*, const char * *fxname* ) [static]

**See also**

http://stackoverflow.com/questions/8884335/print-the-file-name-line-number-and-function

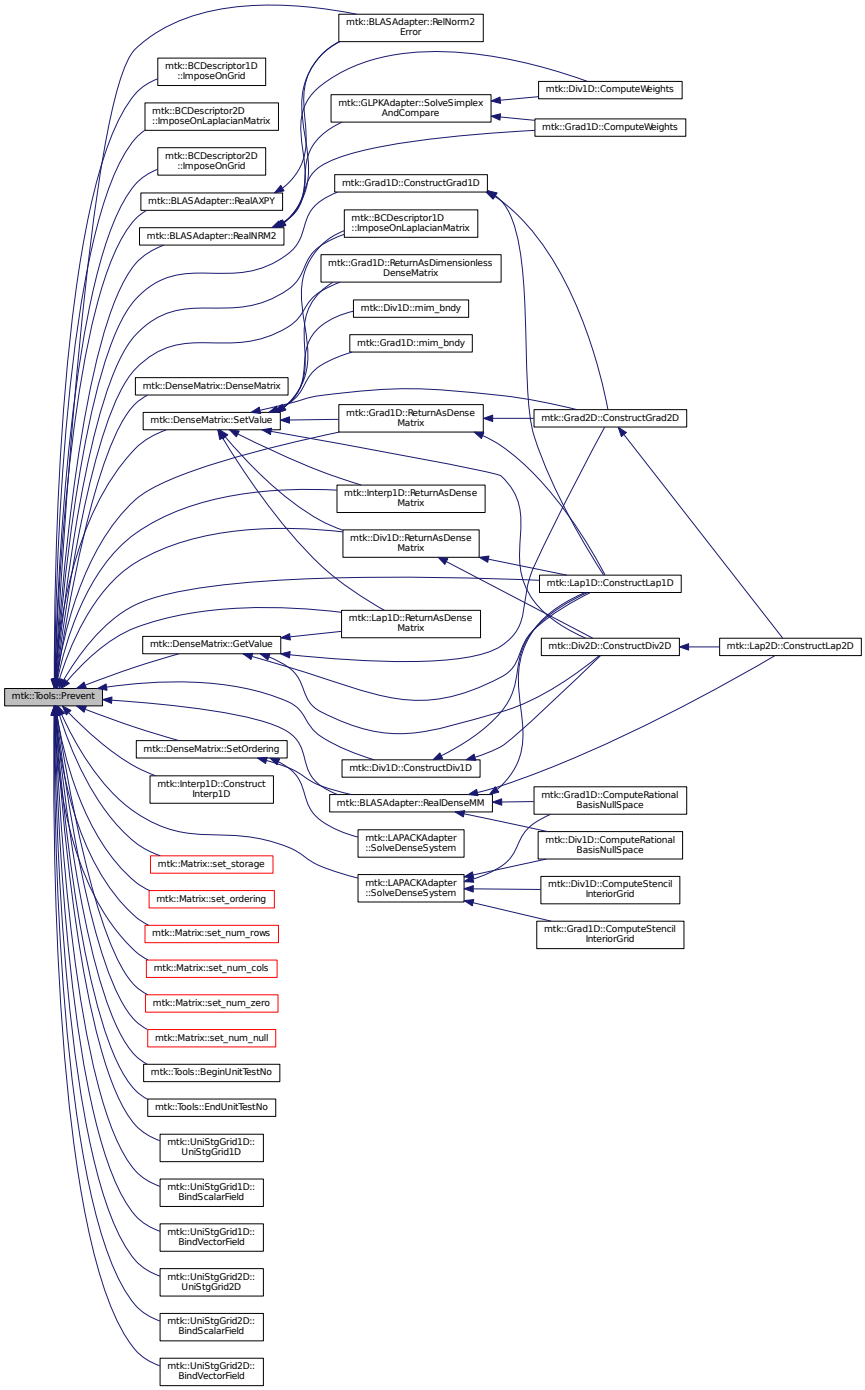
**Parameters**

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

**Todo** Check if this is the best way of stalling execution.

Definition at line 61 of file mtk_tools.cc.

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 117 of file mtk_tools.h.

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

Definition at line 115 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 113 of file mtk_tools.h.

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

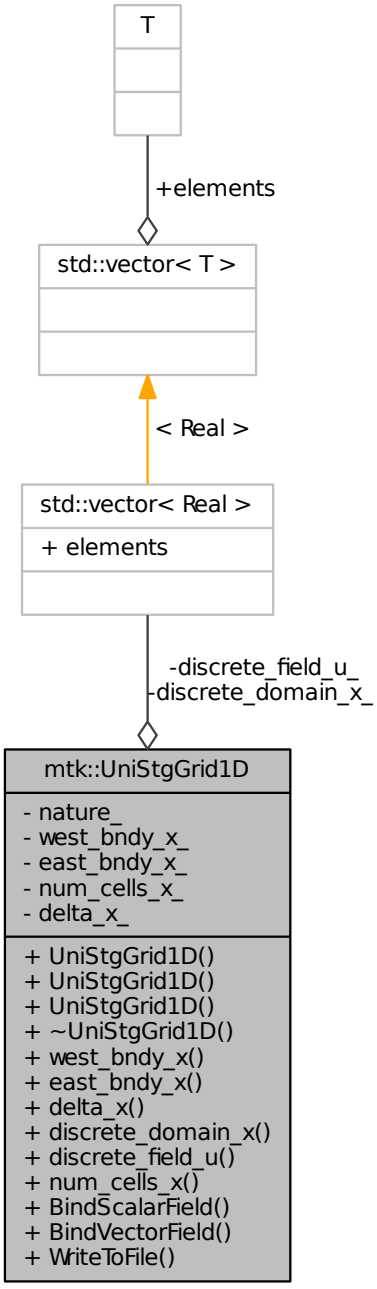
- include/mtk_tools.h
- src/mtk_tools.cc

## 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::FieldNature &nature=mtk::SCALAR)

  *Construct a grid based on spatial discretization parameters.*
- ~UniStgGrid1D ()

  *Destructor.*
- Real west_bndy_x () const

  *Provides access to west boundary spatial coordinate.*
- Real east_bndy_x () const

  *Provides access to east boundary spatial coordinate.*
- Real delta_x () const

  *Provides access to the computed $ x $.*
- Real * discrete_domain_x ()

  *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)

  *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 | *grid* | 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**

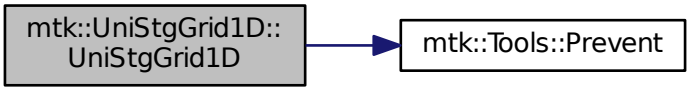
| | | |
|---|---|---|
| in | *west_bndy_x* | Coordinate for the west boundary. |
| in | *east_bndy_x* | Coordinate for the east boundary. |
| in | *num_cells_x* | Number of cells of the required grid. |
| in | *nature* | Nature of the discrete field to hold. |

**See also**

mtk::FieldNature

Definition at line 124 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:




#### 16.18.2.4 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* )

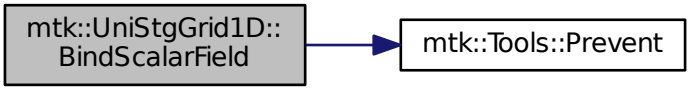
**Parameters**

| | | |
|---|---|---|
| in | *ScalarField* | Pointer to the function implementing the scalar field. |

1. Create collection of spatial coordinates.
2. Create collection of field samples.

Definition at line 176 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:




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

We assume the field to be of the form:

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

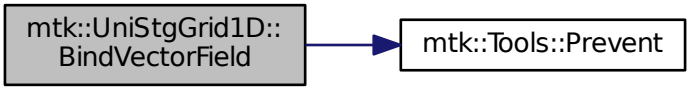
**Parameters**

| | | |
|---|---|---|
| in | *VectorField* | Pointer to the function implementing the vector field. |

1. Create collection of spatial coordinates.
2. Create collection of field samples.

Definition at line 212 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



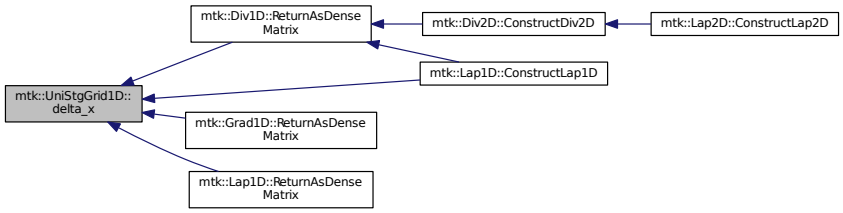
#### 16.18.3.3 mtk::Real mtk::UniStgGrid1D::delta_x ( ) const

**Returns**

Computed $ x $.

Definition at line 156 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:




#### 16.18.3.4 mtk::Real * mtk::UniStgGrid1D::discrete_domain_x ( )

**Returns**

Pointer to the spatial data.

Definition at line 161 of file mtk_uni_stg_grid_1d.cc.

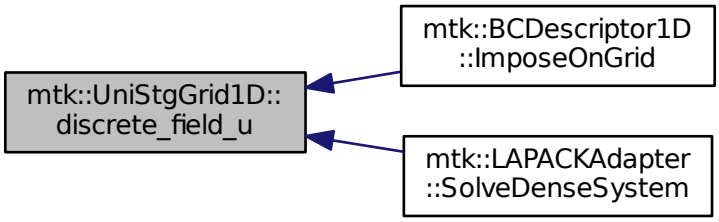
#### 16.18.3.5 mtk::Real * mtk::UniStgGrid1D::discrete_field_u ( )

**Returns**

Pointer to the field data.

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.

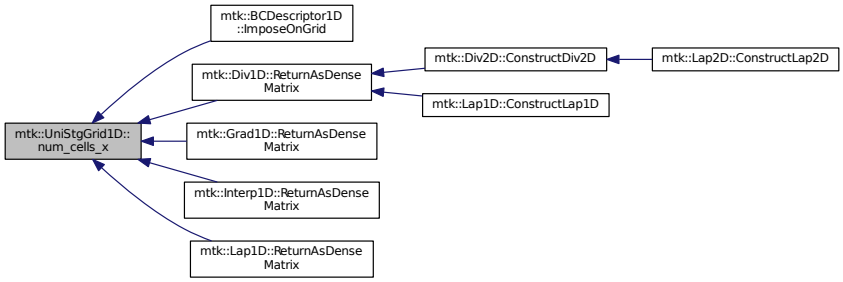
#### 16.18.3.7 int mtk::UniStgGrid1D::num_cells_x ( ) const

**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* )

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |
| in | *space_name* | Name for the first column of the data. |
| in | *field_name* | Name for the second column of the data. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Definition at line 240 of file mtk_uni_stg_grid_1d.cc.

### 16.18.4 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 196 of file mtk_uni_stg_grid_1d.h.

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

Definition at line 190 of file mtk_uni_stg_grid_1d.h.

#### 16.18.5.3 std::vector<Real> mtk::UniStgGrid1D::discrete_field_u_ [private]

Definition at line 191 of file mtk_uni_stg_grid_1d.h.

#### 16.18.5.4 Real mtk::UniStgGrid1D::east_bndy_x_ [private]

Definition at line 194 of file mtk_uni_stg_grid_1d.h.

#### 16.18.5.5 FieldNature mtk::UniStgGrid1D::nature_ [private]

Definition at line 188 of file mtk_uni_stg_grid_1d.h.

#### 16.18.5.6 Real mtk::UniStgGrid1D::num_cells_x_ [private]

Definition at line 195 of file mtk_uni_stg_grid_1d.h.

#### 16.18.5.7 Real mtk::UniStgGrid1D::west_bndy_x_ [private]

Definition at line 193 of file mtk_uni_stg_grid_1d.h.

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

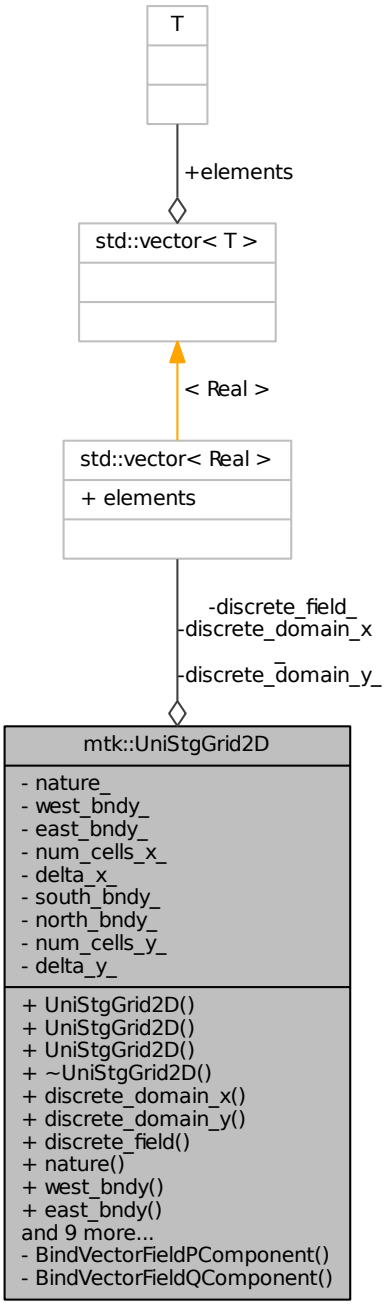
- include/mtk_uni_stg_grid_1d.h
- src/mtk_uni_stg_grid_1d.cc

## 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::S↩CALAR)

  *Construct a grid based on spatial discretization parameters.*
- ∼UniStgGrid2D ()

  *Destructor.*
- Real ∗ discrete_domain_x ()

  *Provides access to the grid spatial data.*
- Real ∗ discrete_domain_y ()

  *Provides access to the grid spatial data.*
- Real ∗ discrete_field ()

  *Provides access to the grid field data.*
- FieldNature nature () const

  *Physical nature of the data bound to the grid.*
- Real west_bndy () const

  *Provides access to west boundary spatial coordinate.*
- Real east_bndy () const

  *Provides access to east boundary spatial coordinate.*
- int num_cells_x () const

  *Provides access to the number of cells of the grid.*
- Real delta_x () const

  *Provides access to the computed $ x $.*
- Real south_bndy () const

  *Provides access to south boundary spatial coordinate.*
- Real north_bndy () const

  *Provides access to north boundary spatial coordinate.*
- int num_cells_y () const

  *Provides access to the number of cells of the grid.*
- Real delta_y () const

  *Provides access to the computed $ y $.*
- 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)

  *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**

| | | |
|---|---|---|
| in | *grid* | Given grid. |

Definition at line 145 of file mtk_uni_stg_grid_2d.cc.

#### 16.19.2.3 mtk::UniStgGrid2D::UniStgGrid2D ( const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const Real & *south_bndy_y*, const Real & *north_bndy_y*, const int & *num_cells_y*, const mtk::FieldNature & *nature* = mtk::SCALAR )

**Parameters**

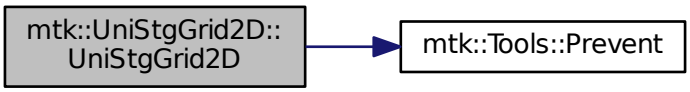
| | | |
|---|---|---|
| in | *west_bndy_x* | Coordinate for the west boundary. |
| in | *east_bndy_x* | Coordinate for the east boundary. |
| in | *num_cells_x* | Number of cells of the required grid. |
| in | *south_bndy_y* | Coordinate for the west boundary. |
| in | *north_bndy_y* | Coordinate for the east boundary. |
| in | *num_cells_y* | Number of cells of the required grid. |
| in | *nature* | Nature of the discrete field to hold. |

**See also**

mtk::FieldNature

Definition at line 169 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:




#### 16.19.2.4 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* )

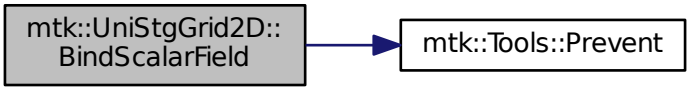
**Parameters**

| | | |
|---|---|---|
| in | *ScalarField* | Pointer to the function implementing the scalar field. |

1. Create collection of spatial coordinates for $x$.
2. Create collection of spatial coordinates for $y$.
3. Create collection of field samples.

Definition at line 250 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:

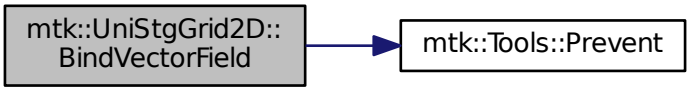
$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

**Parameters**

| | | |
|---|---|---|
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ p $ component of the vector field. |
| in | *VectorFieldP↩ Component* | Pointer to the function implementing the $ q $ component of the vector field. |

Definition at line 393 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 | *BindVectorField↩ PComponent* | Pointer to the function implementing the $ p $ component of the vector field. |

1. Create collection of spatial coordinates for $x$.
2. Create collection of spatial coordinates for $y$.
3. Allocate space for discrete vector field and bind $ p $ component.

Definition at line 300 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 | *BindVectorField↩ QComponent* | Pointer to the function implementing the $ q $ component of the vector field. |

1. Bind $ q $ component, since $ p $ component has already been bound.

Definition at line 365 of file mtk_uni_stg_grid_2d.cc.

#### 16.19.3.5 mtk::Real mtk::UniStgGrid2D::delta_x ( ) const

**Returns**

Computed $ x $.

Definition at line 225 of file mtk_uni_stg_grid_2d.cc.

#### 16.19.3.6 mtk::Real mtk::UniStgGrid2D::delta_y ( ) const

**Returns**

Computed $ y $.

Definition at line 245 of file mtk_uni_stg_grid_2d.cc.

#### 16.19.3.7 Real* mtk::UniStgGrid2D::discrete_domain_x ( )

**Returns**

Pointer to the spatial data.

#### 16.19.3.8 Real* mtk::UniStgGrid2D::discrete_domain_y ( )

**Returns**

Pointer to the spatial data.

#### 16.19.3.9 Real* mtk::UniStgGrid2D::discrete_field ( )

**Returns**

Pointer to the field data.

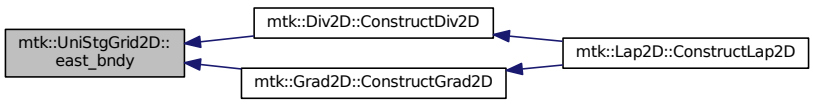
#### 16.19.3.10 mtk::Real mtk::UniStgGrid2D::east_bndy ( ) const

**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:



#### 16.19.3.11 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.

#### 16.19.3.12 mtk::Real mtk::UniStgGrid2D::north_bndy ( ) const

**Returns**

North boundary spatial coordinate.

Definition at line 235 of file mtk_uni_stg_grid_2d.cc.

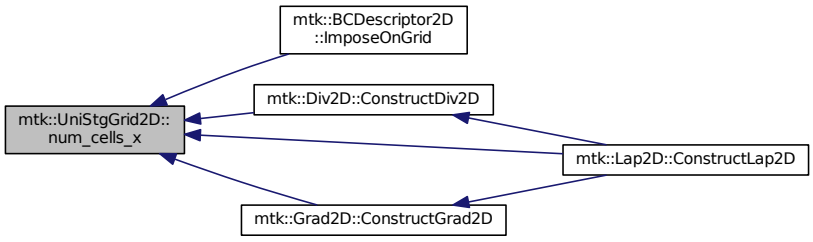
#### 16.19.3.13 int mtk::UniStgGrid2D::num_cells_x ( ) const

**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:



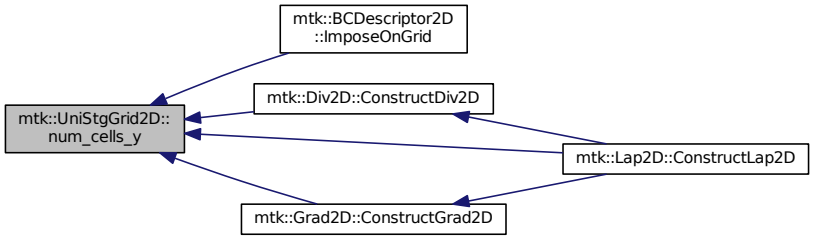

#### 16.19.3.14 int mtk::UniStgGrid2D::num_cells_y ( ) const

**Returns**

Number of cells of the grid.

Definition at line 240 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



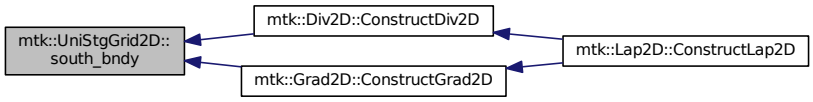

#### 16.19.3.15 mtk::Real mtk::UniStgGrid2D::south_bndy ( ) const

**Returns**

South boundary spatial coordinate.

Definition at line 230 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



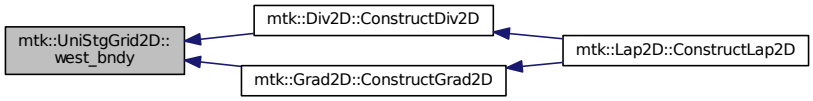

#### 16.19.3.16 mtk::Real mtk::UniStgGrid2D::west_bndy ( ) const

**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:




#### 16.19.3.17 bool mtk::UniStgGrid2D::WriteToFile ( std::string *filename*, std::string *space_name_x*, std::string *space_name_y*, std::string *field_name* )

**Parameters**

| | | |
|---|---|---|
| in | *filename* | Name of the output file. |
| in | *space_name_x* | Name for the first column of the (spatial) data. |
| in | *space_name_y* | Name for the second column of the (spatial) data. |
| in | *field_name* | Name for the second column of the (physical field) data. |

**Returns**

Success of the file writing process.

**See also**

http://www.gnuplot.info/

Write the values of the p component, with a null q component.

Write the values of the q component, with a null p component.

Definition at line 405 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 286 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 291 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 277 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 278 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 279 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 284 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 281 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 289 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 285 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 290 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 288 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 283 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

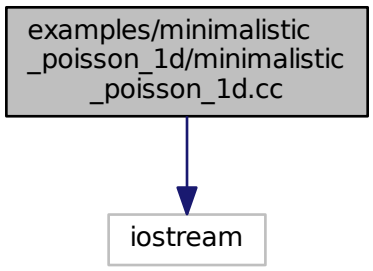
# File Documentation

## 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 /*
00043 Copyright (C) 2015, Computational Science Research Center, San Diego State
00044 University. All rights reserved.
00045
00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
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
00058 3. Redistributions in binary form must reproduce the above copyright notice,
00059 this list of conditions and the following disclaimer in the documentation and/or
00060 other materials provided with the distribution.
00061
00062 4. Usage of the binary form on proprietary applications shall require explicit
00063 prior written permission from the the copyright holders, and due credit should
00064 be given to the copyright holders.
```

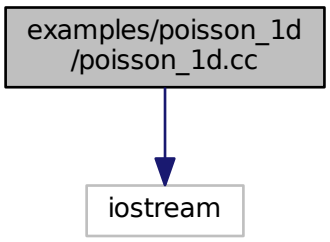
```
00065
00066 5. Neither the name of the copyright holder nor the names of its contributors
00067 may be used to endorse or promote products derived from this software without
00068 specific prior written permission.
00069
00070 The copyright holders provide no reassurances that the source code provided does
00071 not infringe any patent, copyright, or any other intellectual property rights of
00072 third parties. The copyright holders disclaim any liability to any recipient for
00073 claims brought against recipient by any third party for infringement of that
00074 parties intellectual property rights.
00075
00076 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00077 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
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
00080 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00081 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00082 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00083 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00084 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00085 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00086 */
00087
00088 #if __cplusplus == 201103L
00089
00090 #include <iostream>
00091 #include <fstream>
00092 #include <cmath>
00093 #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,
      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

```
00001
00042 /*
00043 Copyright (C) 2015, Computational Science Research Center, San Diego State
00044 University. All rights reserved.
00045
00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
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
00058 3. Redistributions in binary form must reproduce the above copyright notice,
00059 this list of conditions and the following disclaimer in the documentation and/or
00060 other materials provided with the distribution.
00061
00062 4. Usage of the binary form on proprietary applications shall require explicit
```

```
00063 prior written permission from the the copyright holders, and due credit should
00064 be given to the copyright holders.
00065
00066 5. Neither the name of the copyright holder nor the names of its contributors
00067 may be used to endorse or promote products derived from this software without
00068 specific prior written permission.
00069
00070 The copyright holders provide no reassurances that the source code provided does
00071 not infringe any patent, copyright, or any other intellectual property rights of
00072 third parties. The copyright holders disclaim any liability to any recipient for
00073 claims brought against recipient by any third party for infringement of that
00074 parties intellectual property rights.
00075
00076 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00077 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
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
00080 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00081 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00082 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00083 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00084 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00085 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00086 */
00087
00088 #if __cplusplus == 201103L
00089
00090 #include <iostream>
00091 #include <fstream>
00092 #include <cmath>
00093
00094 #include <vector>
00095
00096 #include "mtk.h"
00097
00098 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
00118
00119   mtk::Real lambda = -1.0;
00120   mtk::Real alpha = -exp(lambda);
00121   mtk::Real beta = (exp(lambda) - 1.0)/lambda;
00122   mtk::Real omega = -1.0;
00123   mtk::Real epsilon = 0.0;
00124
00126
00127   mtk::Real west_bndy_x = 0.0;
00128   mtk::Real east_bndy_x = 1.0;
00129   int num_cells_x = 5;
00130
00131   mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00132
00134
00135   int order_of_accuracy{2};  // Desired order of accuracy for approximation.
00136
00137   mtk::Grad1D grad;  // Mimetic gradient operator.
00138
00139   mtk::Lap1D lap;  // Mimetic Laplacian operator.
00140
00141   if (!lap.ConstructLap1D(order_of_accuracy)) {
00142     std::cerr << "Mimetic lap could not be built." << std::endl;
00143     return EXIT_FAILURE;
00144   }
00145
00146   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
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
00170
00171   // Since we need to approximate the first derivative times beta, we must use
00172   // the approximation of the gradient at the boundary. We could extract them
00173   // from the gradient operator as packed in the grad object. BUT, since we have
00174   // generated at matrix containing this operator, we can extract these from the
00175   // matrix.
00176
00177   // Array containing the coefficients for the west boundary condition.
00178   std::vector<mtk::Real> west_coeffs;
00179
00180   for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00181     west_coeffs.push_back(-beta*gradm.GetValue(0, ii));
00182   }
00183
00184   // Array containing the coefficients for the east boundary condition.
00185   std::vector<mtk::Real> east_coeffs;
00186
00187   for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00188     east_coeffs.push_back(beta*gradm.GetValue(gradm.num_rows() - 1,
00189                                               gradm.num_cols() - 1 - ii));
00190   }
00191
00192   // To impose the Dirichlet condition, we simple add its coefficient to the
00193   // first entry of the west, and the last entry of the east array.
00194
00195   west_coeffs[0] += alpha;
00196
00197   east_coeffs[0] += alpha;
00198
00199   // Now that we have the coefficients that should be in the operator, we create
00200   // a boundary condition descriptor object, which will encapsulate the
00201   // complexity of assigning them in the matrix, to complete the construction of
00202   // the mimetic operator.
00203
00204   mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(lapm,
    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
00217
00218   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00219
00220   if (!info) {
00221     std::cout << "System solved! Problem solved!" << std::endl;
00222     std::cout << std::endl;
00223   }
00224   else {
00225     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00226     std::cerr << "Exiting..." << std::endl;
00227     return EXIT_FAILURE;
00228   }
00229
```

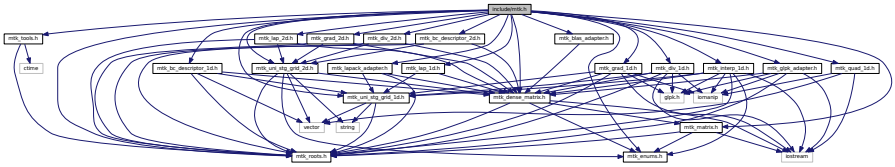
```
00230   std::cout << "Computed solution:" << std::endl;
00231   std::cout << source << std::endl;
00232
00233   source.WriteToFile("poisson_1d_comp_sol.dat", "x", "~u(x)");
00234
00236
00237   mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00238
00239   known_sol.BindScalarField(KnownSolution);
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"
```

Include dependency graph for mtk.h:



### 17.5.1 Detailed Description

This file contains every required header file, thus containing the entire API. In this way, client codes only have to instruct #include "mtk.h".

#### Warning

IT IS EXTREMELY IMPORTANT THAT THE HEADERS ARE ADDED TO THIS FILE IN A SPECIFIC ORDER; THAT IS, CONSIDERING THE DEPENDENCE BETWEEN THE CLASSES THESE CONTAIN!

#### Author

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

Definition in file mtk.h.

## 17.6 mtk.h

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
00039 5. Neither the name of the copyright holder nor the names of its contributors
00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
00042
00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
```

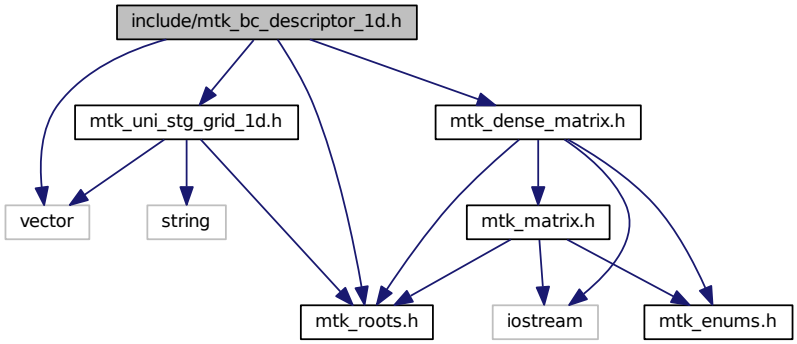
```
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00050 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
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

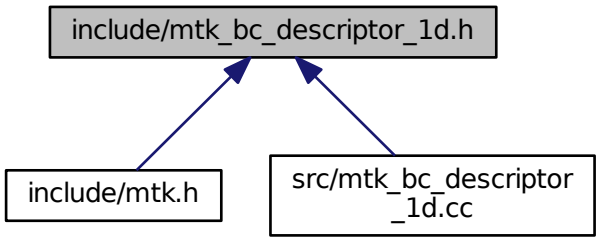
Enforces boundary conditions in either the operator or the grid.

```
#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

## 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

```
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 <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:
00077   static void ImposeOnLaplacianMatrix(DenseMatrix &matrix,
00078                                       const std::vector<Real> &west,
00079                                       const std::vector<Real> &east);
00080
00088   static void ImposeOnGrid(UniStgGrid1D &grid,
00089                            const Real &epsilon,
00090                            const Real &omega);
00091 };
```

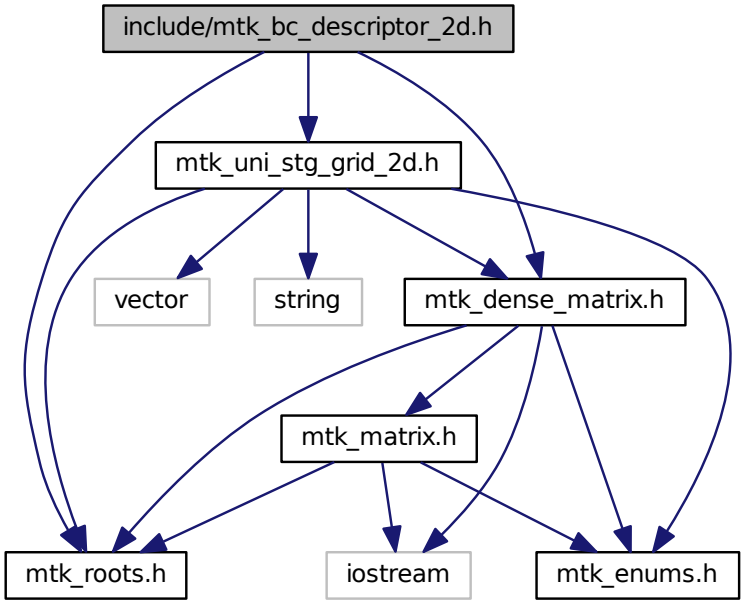
```
00092 }
00093 #endif  // End of: MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
```

## 17.9 include/mtk_bc_descriptor_2d.h File Reference

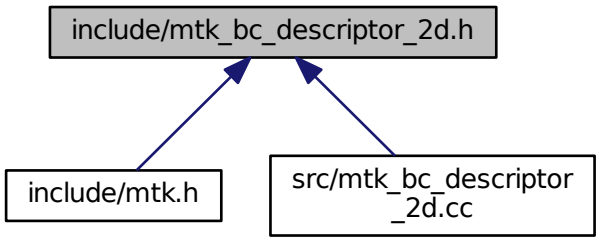
Enforces boundary conditions in either the operator or the grid.

```
#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

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 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.

#### 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
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
```

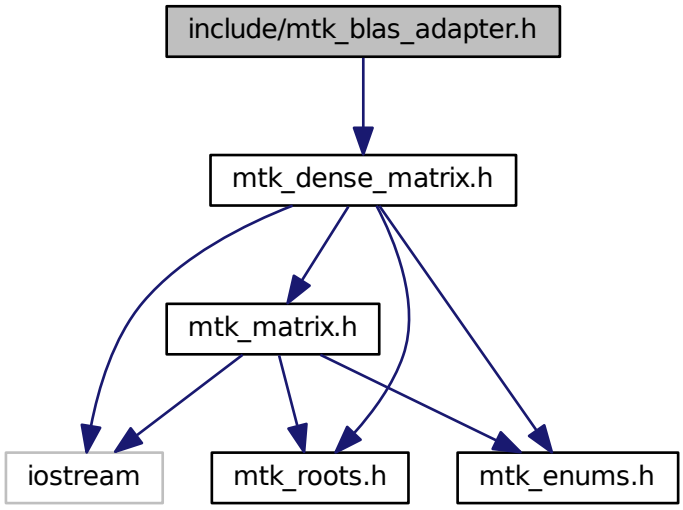
```
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
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 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00058 #define MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class BCDescriptor2D {
00067  public:
00077   static void ImposeOnLaplacianMatrix(DenseMatrix &matrix,
00078                                       Real (*west)(int ii, int jj),
00079                                       Real (*east)(int ii, int jj),
00080                                       Real (*south)(int ii, int jj),
00081                                       Real (*north)(int ii, int jj));
00082
00092   static void ImposeOnGrid(UniStgGrid2D &grid,
00093                            Real (*west)(Real xx, Real yy),
00094                            Real (*east)(Real xx, Real yy),
00095                            Real (*south)(Real xx, Real yy),
00096                            Real (*north)(Real xx, Real yy));
00097 };
00098 }
00099 #endif  // End of: MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
```

## 17.11 include/mtk_blas_adapter.h File Reference

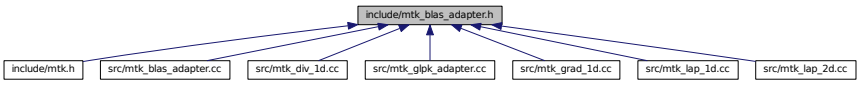
Adapter class for the BLAS API.

```
#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
00024 /*
00025 Copyright (C) 2015, Computational Science Research Center, San Diego State
00026 University. All rights reserved.
00027
00028 Redistribution and use in source and binary forms, with or without modification,
00029 are permitted provided that the following conditions are met:
00030
00031 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00032 and a copy of the modified files should be reported once modifications are
00033 completed, unless these modifications are made through the project's GitHub
00034 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00035 should be developed and included in any deliverable.
00036
00037 2. Redistributions of source code must be done through direct
00038 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00039
00040 3. Redistributions in binary form must reproduce the above copyright notice,
00041 this list of conditions and the following disclaimer in the documentation and/or
00042 other materials provided with the distribution.
00043
00044 4. Usage of the binary form on proprietary applications shall require explicit
00045 prior written permission from the the copyright holders, and due credit should
00046 be given to the copyright holders.
00047
00048 5. Neither the name of the copyright holder nor the names of its contributors
00049 may be used to endorse or promote products derived from this software without
00050 specific prior written permission.
00051
00052 The copyright holders provide no reassurances that the source code provided does
00053 not infringe any patent, copyright, or any other intellectual property rights of
00054 third parties. The copyright holders disclaim any liability to any recipient for
00055 claims brought against recipient by any third party for infringement of that
00056 parties intellectual property rights.
00057
00058 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00059 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
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 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00071 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00072
00073 #include "mtk_dense_matrix.h"
```

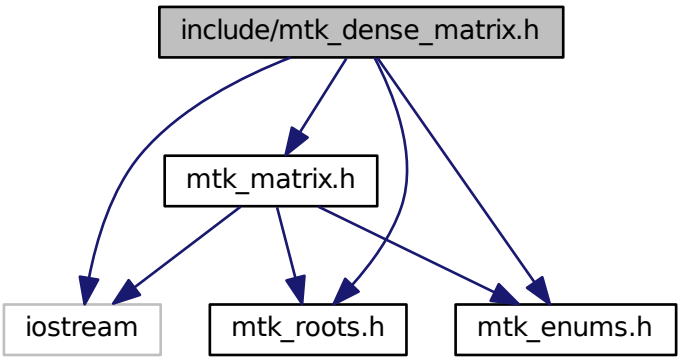
```
00074
00075 namespace mtk {
00076
00096 class BLASAdapter {
00097  public:
00106   static Real RealNRM2(Real *in, int &in_length);
00107
00124   static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00125
00140   static Real RelNorm2Error(Real *computed, Real *known, int length);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

## 17.13 include/mtk_dense_matrix.h File Reference

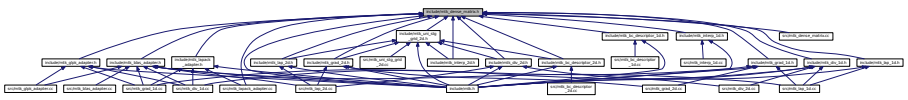
Defines a common dense matrix, using a 1D array.

```
#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-intrincated data structure implementing matrices. This is the purpose of this class: to be used for prototypes of new code for small test cases. In every other instance, this should be replaced by the most appropriate sparse matrix.

#### Author

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

#### Note

We prefer composition to inheritance [Reedy, 2011]. The main reason for this preference is that inheritance produces a more tightly coupled design. When a class inherits from another type be it public, protected, or private inheritance the subclass gains access to all public and protected members of the base class, whereas with composition, the class is only coupled to the public members of the other class. Furthermore, if you only hold a pointer to the other object, then your interface can use a forward declaration of the class rather than #include its full definition. This results in greater compile-time insulation and improves the time it takes to compile your code.

Definition in file mtk_dense_matrix.h.

## 17.14 mtk_dense_matrix.h

```
00001
00023 /*
00024 Copyright (C) 2015, Computational Science Research Center, San Diego State
00025 University. All rights reserved.
00026
00027 Redistribution and use in source and binary forms, with or without modification,
00028 are permitted provided that the following conditions are met:
00029
00030 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
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
00039 3. Redistributions in binary form must reproduce the above copyright notice,
00040 this list of conditions and the following disclaimer in the documentation and/or
00041 other materials provided with the distribution.
00042
00043 4. Usage of the binary form on proprietary applications shall require explicit
00044 prior written permission from the the copyright holders, and due credit should
00045 be given to the copyright holders.
00046
00047 5. Neither the name of the copyright holder nor the names of its contributors
```

```
00048 may be used to endorse or promote products derived from this software without
00049 specific prior written permission.
00050
00051 The copyright holders provide no reassurances that the source code provided does
00052 not infringe any patent, copyright, or any other intellectual property rights of
00053 third parties. The copyright holders disclaim any liability to any recipient for
00054 claims brought against recipient by any third party for infringement of that
00055 parties intellectual property rights.
00056
00057 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00058 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00059 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00060 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00061 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00062 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00063 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00064 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00065 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00066 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00067 */
00068
00069 #ifndef MTK_INCLUDE_DENSE_MATRIX_H_
00070 #define MTK_INCLUDE_DENSE_MATRIX_H_
00071
00072 #include <iostream>
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_enums.h"
00076 #include "mtk_matrix.h"
00077
00078 namespace mtk {
00079
00092 class DenseMatrix {
00093  public:
00095   friend std::ostream& operator <<(std::ostream &stream, DenseMatrix &in);
00096
00098   DenseMatrix& operator =(const DenseMatrix &in);
00099
00101   bool operator ==(const DenseMatrix &in);
00102
00104   DenseMatrix();
00105
00111   DenseMatrix(const DenseMatrix &in);
00112
00121   DenseMatrix(const int &num_rows, const int &num_cols);
00122
00148   DenseMatrix(const int &rank, const bool &padded, const bool &transpose);
00149
00183   DenseMatrix(const Real *gen,
00184               const int &gen_length,
00185               const int &pro_length,
00186               const bool &transpose);
00187
00189   ~DenseMatrix();
00190
00196   Matrix matrix_properties() const;
00197
00203   int num_rows() const;
00204
00210   int num_cols() const;
00211
00217   Real* data() const;
00218
00226   void SetOrdering(mtk::MatrixOrdering oo);
00227
00236   Real GetValue(const int &row_coord, const int &col_coord) const;
00237
00245   void SetValue(const int &row_coord,
00246                 const int &col_coord,
00247                 const Real &val);
00248
00250   void Transpose();
00251
00253   void OrderRowMajor();
00254
00256   void OrderColMajor();
00257
00268   static DenseMatrix Kron(const DenseMatrix &aa, const
      DenseMatrix &bb);
00269
00279   bool WriteToFile(std::string filename);
```

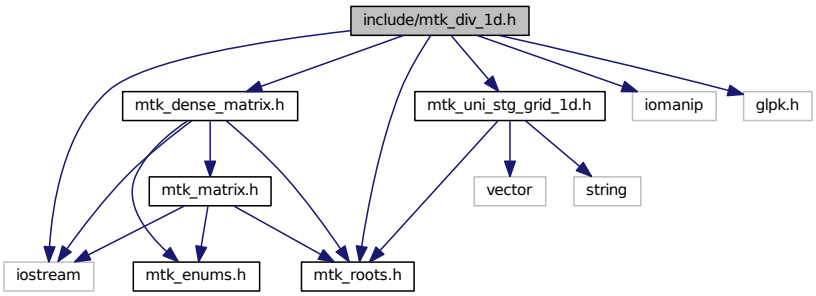
```
00280
00281  private:
00282   Matrix matrix_properties_;
00283
00284   Real *data_;
00285 };
00286 }
00287 #endif  // End of: MTK_INCLUDE_MTK_DENSE_MATRIX_H_
```

## 17.15 include/mtk_div_1d.h File Reference

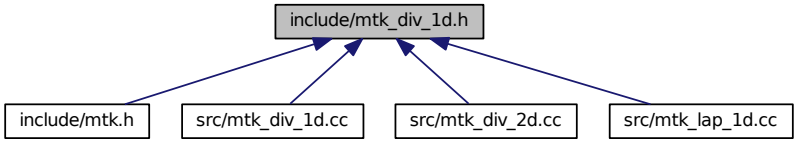
Includes the definition of the class Div1D.

```
#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

```
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 #ifndef MTK_INCLUDE_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>
```

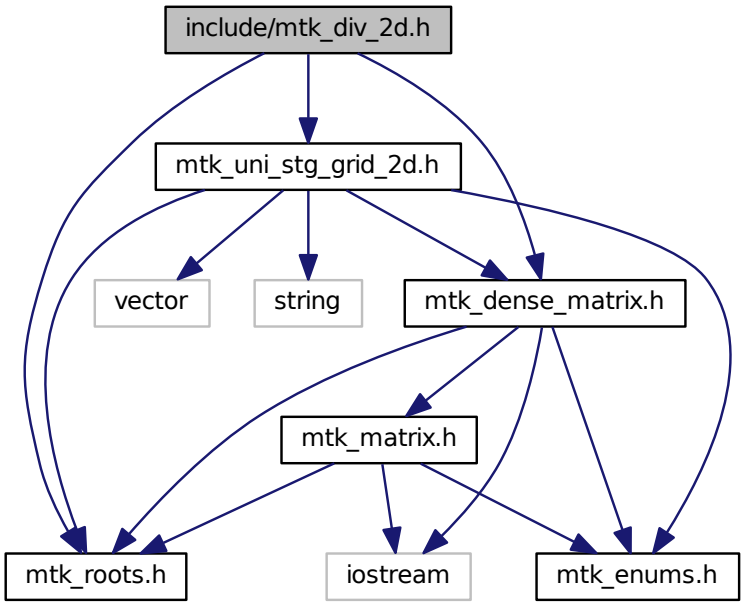
```
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Div1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream,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

## 17.17 include/mtk_div_2d.h File Reference

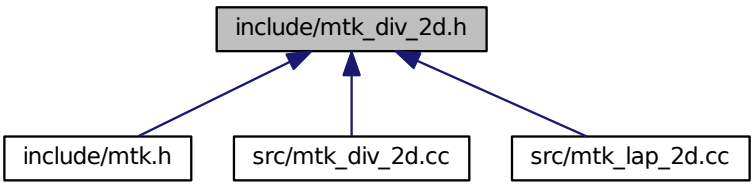
Includes the definition of the class Div2D.

```
#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

### 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

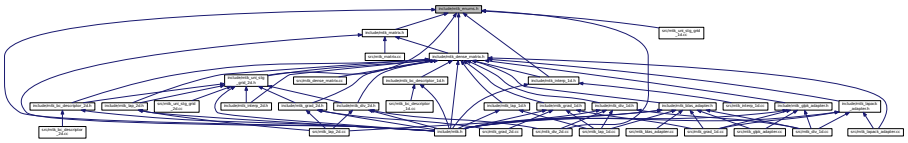
```
00001
00011 /*
00012 Copyright (C) 2015, Computational Science Research Center, San Diego State
00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
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 #ifndef MTK_INCLUDE_MTK_DIV_2D_H_
00058 #define MTK_INCLUDE_MTK_DIV_2D_H_
00059
00060 #include "mtk_roots.h"
```

```
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class Div2D {
00067  public:
00069   Div2D();
00070
00076   Div2D(const Div2D &div);
00077
00079   ~Div2D();
00080
00086   bool ConstructDiv2D(const UniStgGrid2D &grid,
00087                       int order_accuracy = kDefaultOrderAccuracy,
00088                       Real mimetic_threshold = kDefaultMimeticThreshold);
00089
00095   DenseMatrix ReturnAsDenseMatrix();
00096
00097  private:
00098   DenseMatrix divergence_;
00099
00100   int order_accuracy_;
00101
00102   Real mimetic_threshold_;
00103 };
00104 }
00105 #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

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_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,
```

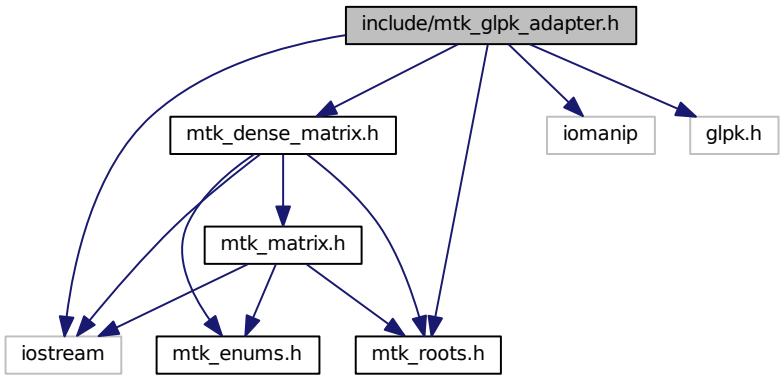
```
00097   COL_MAJOR
00098 };
00099
00113 enum FieldNature {
00114   SCALAR,
00115   VECTOR
00116 };
00117
00127 enum DirInterp {
00128   SCALAR_TO_VECTOR,
00129   VECTOR_TO_SCALAR
00130 };
00131 }
00132 #endif  // End of: MTK_INCLUDE_ENUMS_H_
```

## 17.21 include/mtk_glpk_adapter.h File Reference

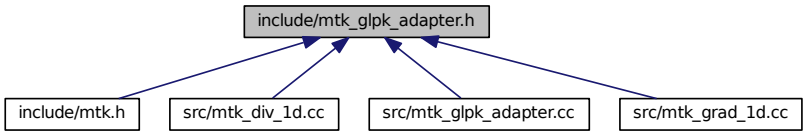
Adapter class for the GLPK API.

```
#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

```
00001
00019 /*
00020 Copyright (C) 2015, Computational Science Research Center, San Diego State
00021 University. All rights reserved.
00022
00023 Redistribution and use in source and binary forms, with or without modification,
00024 are permitted provided that the following conditions are met:
00025
00026 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00034
00035 3. Redistributions in binary form must reproduce the above copyright notice,
00036 this list of conditions and the following disclaimer in the documentation and/or
00037 other materials provided with the distribution.
00038
00039 4. Usage of the binary form on proprietary applications shall require explicit
00040 prior written permission from the the copyright holders, and due credit should
00041 be given to the copyright holders.
00042
00043 5. Neither the name of the copyright holder nor the names of its contributors
00044 may be used to endorse or promote products derived from this software without
00045 specific prior written permission.
00046
00047 The copyright holders provide no reassurances that the source code provided does
```

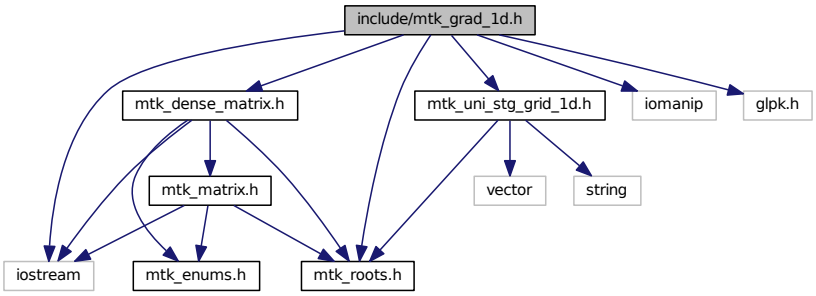
```
00048 not infringe any patent, copyright, or any other intellectual property rights of
00049 third parties. The copyright holders disclaim any liability to any recipient for
00050 claims brought against recipient by any third party for infringement of that
00051 parties intellectual property rights.
00052
00053 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00054 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00055 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00056 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00057 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00058 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00059 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00066 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00067
00068 #include <iostream>
00069 #include <iomanip>
00070
00071 #include "glpk.h"
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075
00076 namespace mtk {
00077
00101 class GLPKAdapter {
00102  public:
00123   static mtk::Real SolveSimplexAndCompare(
      mtk::Real *A,
00124                                           int nrows,
00125                                           int ncols,
00126                                           int kk,
00127                                           mtk::Real *hh,
00128                                           mtk::Real *qq,
00129                                           int robjective,
00130                                           mtk::Real mimetic_tol,
00131                                           int copy);
00132 };
00133 }
00134 #endif  // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_
```

## 17.23 include/mtk_grad_1d.h File Reference

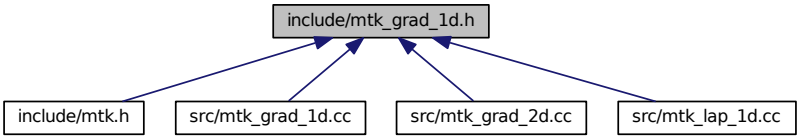
Includes the definition of the class Grad1D.

```
#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

```
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 #ifndef MTK_INCLUDE_GRAD_1D_H_
00058 #define MTK_INCLUDE_GRAD_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Grad1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00085
00087   Grad1D();
00088
00094   Grad1D(const Grad1D &grad);
00095
00097   ~Grad1D();
00098
00104   bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00105                        Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112   int num_bndy_coeffs() const;
00113
00119   Real *coeffs_interior() const;
00120
```

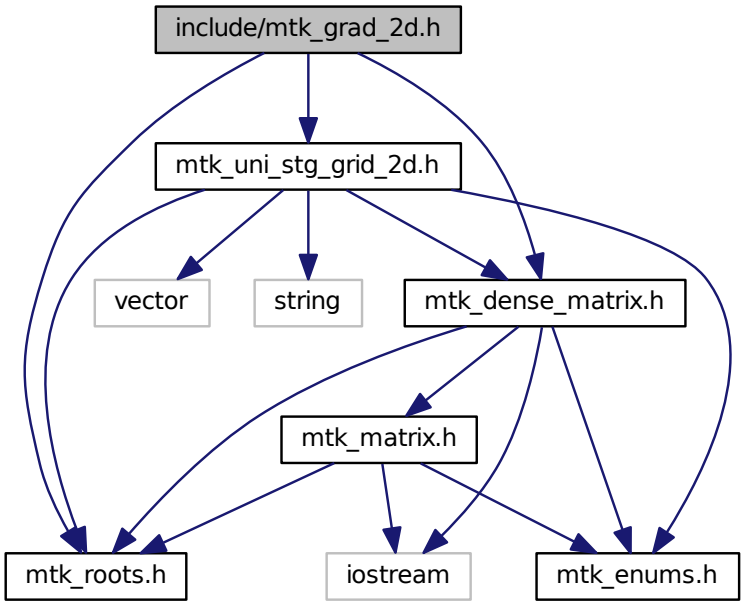
```
00126   Real *weights_crs(void) const;
00127
00133   Real *weights_cbs(void) const;
00134
00140   DenseMatrix mim_bndy() const;
00141
00147   DenseMatrix ReturnAsDenseMatrix(Real west,
      Real east, int num_cells_x);
00148
00154   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid);
00155
00161   DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x);
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

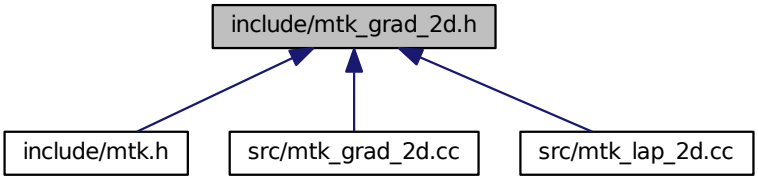
Includes the definition of the class Grad2D.

```
#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

## 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 (CBSA).

**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

```
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 #ifndef MTK_INCLUDE_MTK_GRAD_2D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class Grad2D {
00067  public:
00069   Grad2D();
00070
```

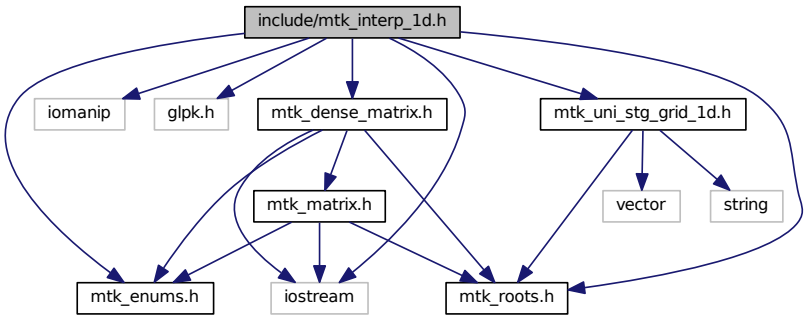
```
00076   Grad2D(const Grad2D &grad);
00077
00079   ~Grad2D();
00080
00086   bool ConstructGrad2D(const UniStgGrid2D &grid,
00087                        int order_accuracy = kDefaultOrderAccuracy,
00088                        Real mimetic_threshold = kDefaultMimeticThreshold);
00089
00095   DenseMatrix ReturnAsDenseMatrix();
00096
00097  private:
00098   DenseMatrix gradient_;
00099
00100   int order_accuracy_;
00101
00102   Real mimetic_threshold_;
00103 };
00104 }
00105 #endif  // End of: MTK_INCLUDE_MTK_GRAD_2D_H_
```

## 17.27 include/mtk_interp_1d.h File Reference

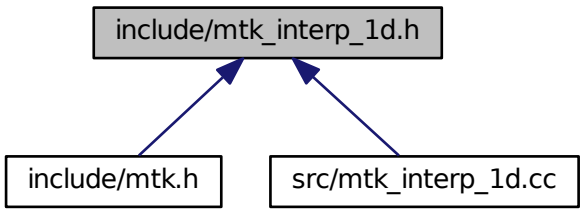
Includes the definition of the class Interp1D.

```
#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

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
```

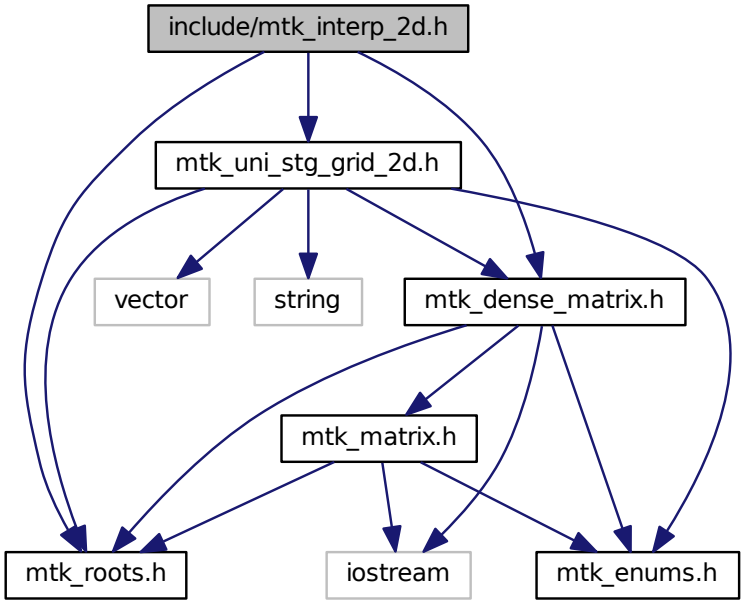
```
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_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);
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

### 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

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_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
00067 class Interp2D {
00068  public:
00070   Interp2D();
00071
00077   Interp2D(const Interp2D &interp);
00078
00080   ~Interp2D();
00081
00087   DenseMatrix ConstructInterp2D(const UniStgGrid2D &grid,
00088                                 int order_accuracy = kDefaultOrderAccuracy,
```

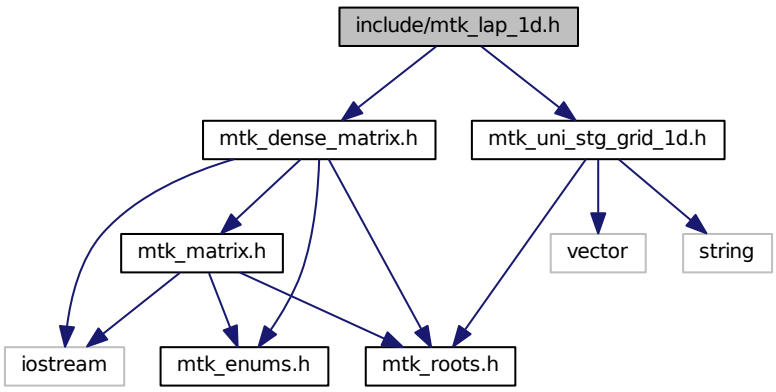
```
00089                             Real mimetic_threshold =
      kDefaultMimeticThreshold);
00090
00096   DenseMatrix ReturnAsDenseMatrix();
00097
00098  private:
00099   DenseMatrix interpolator_;
00100
00101   int order_accuracy_;
00102
00103   Real mimetic_threshold_;
00104 };
00105 }
00106 #endif  // End of: MTK_INCLUDE_MTK_INTERP_2D_H_
```

## 17.31 include/mtk_lap_1d.h File Reference

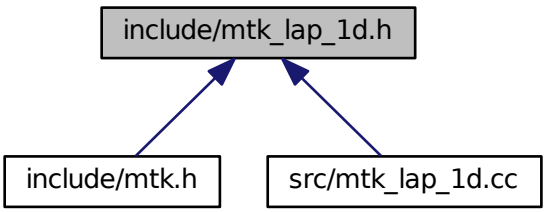
Includes the definition of the class Lap1D.

```
#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

```
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
```

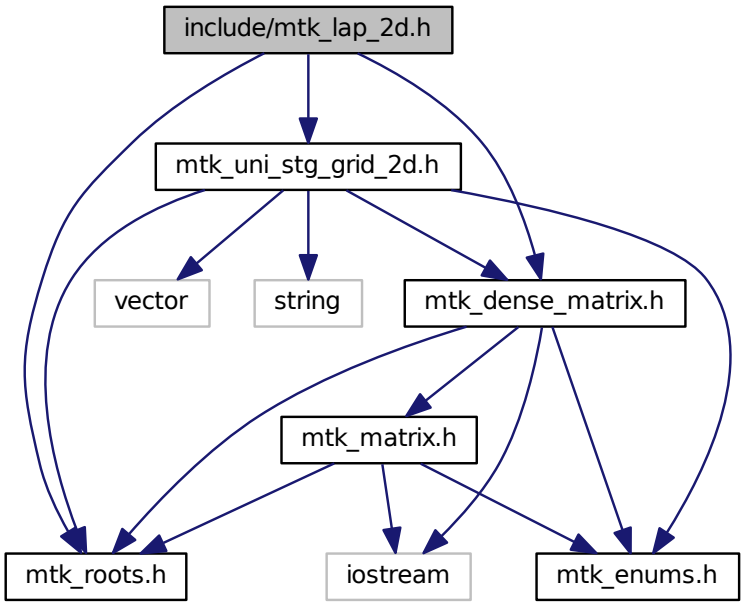
```
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the 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 #ifndef MTK_INCLUDE_LAP_1D_H_
00058 #define MTK_INCLUDE_LAP_1D_H_
00059
00060 #include "mtk_dense_matrix.h"
00061
00062 #include "mtk_uni_stg_grid_1d.h"
00063
00064 namespace mtk {
00065
00076 class Lap1D {
00077  public:
00079   friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00080
00082   Lap1D();
00083
00089   Lap1D(const Lap1D &lap);
00090
00092   ~Lap1D();
00093
00099   bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00100                       Real mimetic_threshold = kDefaultMimeticThreshold);
00101
00107   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid);
00108
00114   mtk::Real* data(const UniStgGrid1D &grid);
00115
00116  private:
00117   int order_accuracy_;
00118   int laplacian_length_;
00119
00120   Real *laplacian_;
00121
00122   Real mimetic_threshold_;
00123 };
00124 }
00125 #endif  // End of: MTK_INCLUDE_LAP_1D_H_
```

## 17.33 include/mtk_lap_2d.h File Reference

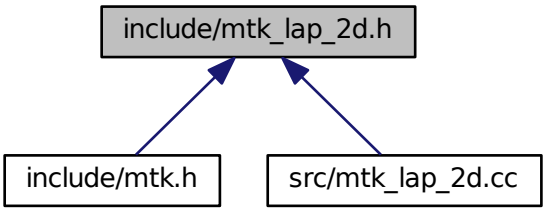
Includes the implementation of the class Lap2D.

```
#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

### 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

```
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 #ifndef MTK_INCLUDE_MTK_LAP_2D_H_
00058 #define MTK_INCLUDE_MTK_LAP_2D_H_
00059
00060 #include "mtk_roots.h"
```

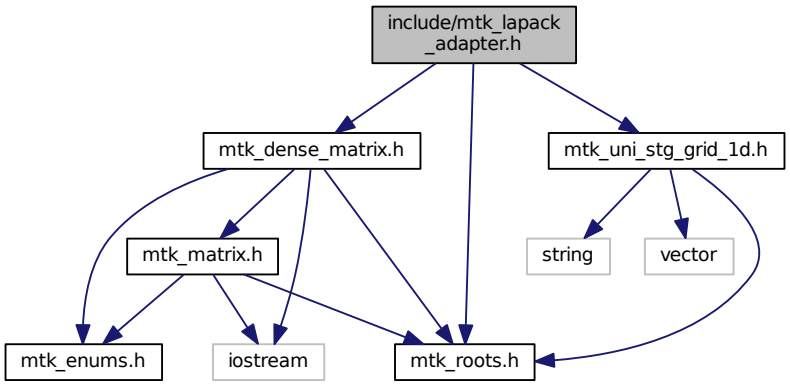
```
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class Lap2D {
00067  public:
00069   Lap2D();
00070
00076   Lap2D(const Lap2D &lap);
00077
00079   ~Lap2D();
00080
00086   bool ConstructLap2D(const UniStgGrid2D &grid,
00087                       int order_accuracy = kDefaultOrderAccuracy,
00088                       Real mimetic_threshold = kDefaultMimeticThreshold);
00089
00095   DenseMatrix ReturnAsDenseMatrix();
00096
00102   mtk::Real* data();
00103
00104  private:
00105   DenseMatrix laplacian_;
00106
00107   int order_accuracy_;
00108
00109   Real mimetic_threshold_;
00110 };
00111 }
00112 #endif  // End of: MTK_INCLUDE_MTK_LAP_2D_H_
```

## 17.35 include/mtk_lapack_adapter.h File Reference

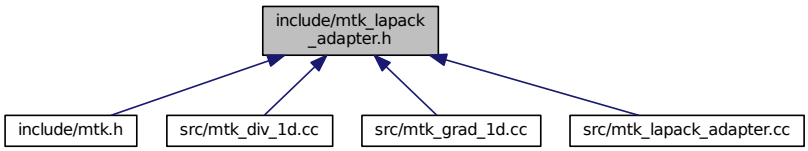
Adapter class for the LAPACK API.

```
#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

```
00001
00019 /*
00020 Copyright (C) 2015, Computational Science Research Center, San Diego State
00021 University. All rights reserved.
00022
00023 Redistribution and use in source and binary forms, with or without modification,
00024 are permitted provided that the following conditions are met:
00025
00026 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00027 and a copy of the modified files should be reported once modifications are
```

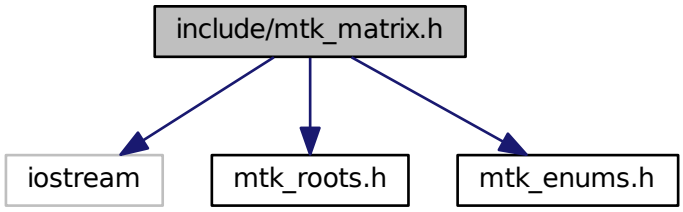
```
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00034
00035 3. Redistributions in binary form must reproduce the above copyright notice,
00036 this list of conditions and the following disclaimer in the documentation and/or
00037 other materials provided with the distribution.
00038
00039 4. Usage of the binary form on proprietary applications shall require explicit
00040 prior written permission from the the copyright holders, and due credit should
00041 be given to the copyright holders.
00042
00043 5. Neither the name of the copyright holder nor the names of its contributors
00044 may be used to endorse or promote products derived from this software without
00045 specific prior written permission.
00046
00047 The copyright holders provide no reassurances that the source code provided does
00048 not infringe any patent, copyright, or any other intellectual property rights of
00049 third parties. The copyright holders disclaim any liability to any recipient for
00050 claims brought against recipient by any third party for infringement of that
00051 parties intellectual property rights.
00052
00053 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00054 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00055 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00056 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00057 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00058 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00059 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00066 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00067
00068 #include "mtk_roots.h"
00069 #include "mtk_dense_matrix.h"
00070 #include "mtk_uni_stg_grid_1d.h"
00071
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::UniStgGrid1D &rhs);
00132
00144   static int SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00145                                          mtk::Real *ob_,
00146                                          int ob_ld_);
00147
00159   static mtk::DenseMatrix QRFactorDenseMatrix(
      DenseMatrix &matrix);
00160 };
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 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
```

```
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #ifndef MTK_INCLUDE_MATRIX_H_
00057 #define MTK_INCLUDE_MATRIX_H_
00058
00059 #include <iostream>
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_enums.h"
00063
00064 namespace mtk {
00065
00075 class Matrix {
00076  public:
00078   Matrix();
00079
00085   Matrix(const Matrix &in);
00086
00088   ~Matrix();
00089
00095   MatrixStorage storage() const;
00096
00102   MatrixOrdering ordering() const;
00103
00109   int num_rows() const;
00110
00116   int num_cols() const;
00117
00123   int num_values() const;
00124
00134   int ld() const;
00135
00141   int num_zero() const;
00142
00148   int num_non_zero() const;
00149
00157   int num_null() const;
00158
00166   int num_non_null() const;
```

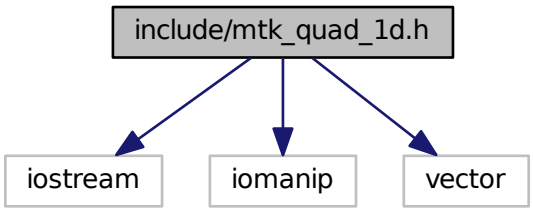
```
00167
00173   int kl() const;
00174
00180   int ku() const;
00181
00187   int bandwidth() const;
00188
00196   Real abs_density() const;
00197
00205   Real rel_density() const;
00206
00214   Real abs_sparsity() const;
00215
00223   Real rel_sparsity() const;
00224
00232   void set_storage(const MatrixStorage &tt);
00233
00241   void set_ordering(const MatrixOrdering &oo);
00242
00248   void set_num_rows(int num_rows);
00249
00255   void set_num_cols(int num_cols);
00256
00262   void set_num_zero(int in);
00263
00269   void set_num_null(int in);
00270
00272   void IncreaseNumZero();
00273
00275   void IncreaseNumNull();
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

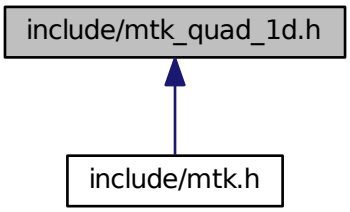
Includes the definition of the class Quad1D.

```
#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

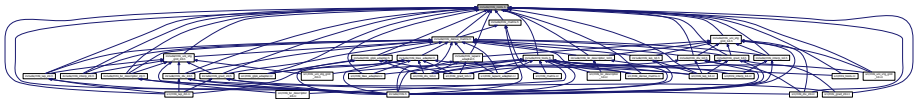
```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
00039 5. Neither the name of the copyright holder nor the names of its contributors
00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
00042
00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00050 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #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);
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::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

```
00001
00017 /*
00018 Copyright (C) 2015, Computational Science Research Center, San Diego State
00019 University. All rights reserved.
00020
00021 Redistribution and use in source and binary forms, with or without modification,
00022 are permitted provided that the following conditions are met:
00023
00024 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00025 and a copy of the modified files should be reported once modifications are
00026 completed, unless these modifications are made through the project's GitHub
00027 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00028 should be developed and included in any deliverable.
00029
00030 2. Redistributions of source code must be done through direct
00031 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00032
00033 3. Redistributions in binary form must reproduce the above copyright notice,
00034 this list of conditions and the following disclaimer in the documentation and/or
00035 other materials provided with the distribution.
00036
00037 4. Usage of the binary form on proprietary applications shall require explicit
00038 prior written permission from the the copyright holders, and due credit should
00039 be given to the copyright holders.
00040
00041 5. Neither the name of the copyright holder nor the names of its contributors
00042 may be used to endorse or promote products derived from this software without
00043 specific prior written permission.
00044
00045 The copyright holders provide no reassurances that the source code provided does
00046 not infringe any patent, copyright, or any other intellectual property rights of
00047 third parties. The copyright holders disclaim any liability to any recipient for
00048 claims brought against recipient by any third party for infringement of that
00049 parties intellectual property rights.
00050
00051 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00052 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00053 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00054 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00055 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00056 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00057 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00058 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00059 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00060 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00061 */
00062
00063 #ifndef MTK_INCLUDE_ROOTS_H_
00064 #define MTK_INCLUDE_ROOTS_H_
00065
00071 namespace mtk {
```

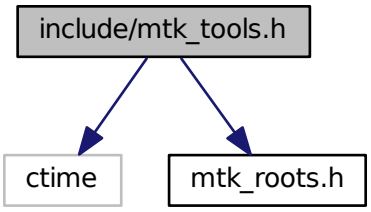
```
00072
00080 #ifdef MTK_PRECISION_DOUBLE
00081 typedef double Real;
00082 #else
00083 typedef float Real;
00084 #endif
00085
00103 #ifdef MTK_PRECISION_DOUBLE
00104 const double kZero{0.0};
00105 const double kOne{1.0};
00106 #else
00107 const float kZero{0.0f};
00108 const float kOne{1.0f};
00109 #endif
00110
00118 #ifdef MTK_PRECISION_DOUBLE
00119 const double kDefaultTolerance{1e-7};
00120 #else
00121 const float kDefaultTolerance{1e-7f};
00122 #endif
00123
00133 const int kDefaultOrderAccuracy{2};
00134
00144 #ifdef MTK_PRECISION_DOUBLE
00145 const double kDefaultMimeticThreshold{1e-6};
00146 #else
00147 const float kDefaultMimeticThreshold{1e-6f};
00148 #endif
00149
00157 const int kCriticalOrderAccuracyDiv{8};
00158
00166 const int kCriticalOrderAccuracyGrad{10};
00167 }
00168 #endif  // End of: MTK_INCLUDE_ROOTS_H_
```

## 17.43 include/mtk_tools.h File Reference

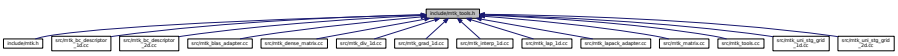
Tool manager class.

```
#include <ctime>
#include "mtk_roots.h"
```

Include dependency graph for mtk_tools.h:




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



### Classes

- class mtk::Tools

  *Tool manager class.*

### Namespaces

- mtk

  *Mimetic Methods Toolkit namespace.*

### 17.43.1 Detailed Description

Basic utilities.

**Author**

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

Definition in file mtk_tools.h.

## 17.44 mtk_tools.h

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
```

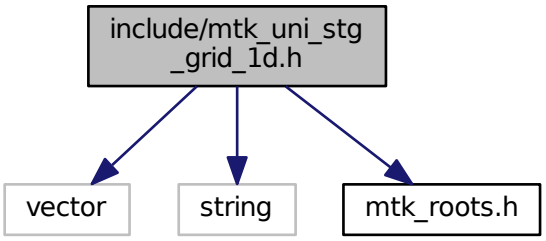
```
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #ifndef MTK_INCLUDE_TOOLS_H_
00057 #define MTK_INCLUDE_TOOLS_H_
00058
00059 #include <ctime>
00060
00061 #include "mtk_roots.h"
00062
00063 namespace mtk {
00064
00074 class Tools {
00075  public:
00086   static void Prevent(const bool complement,
00087                       const char *fname,
00088                       int lineno,
00089                       const char *fxname);
00090
00096   static void BeginUnitTestNo(const int &nn);
00097
00103   static void EndUnitTestNo(const int &nn);
00104
00110   static void Assert(const bool condition);
00111
00112  private:
00113   static int test_number_;
00114
00115   static Real duration_;
00116
00117   static clock_t begin_time_;
00118 };
00119 }
00120 #endif  // End of: MTK_INCLUDE_TOOLS_H_
```

## 17.45 include/mtk_uni_stg_grid_1d.h File Reference

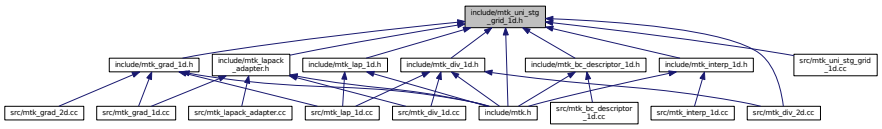
Definition of an 1D uniform staggered grid.

```
#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

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
```

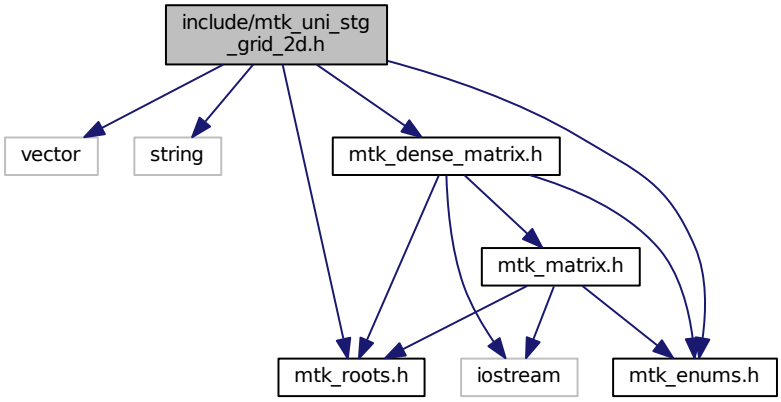
```
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_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
00136   Real *discrete_domain_x();
00137
00143   Real *discrete_field_u();
00144
00150   int num_cells_x() const;
00151
00157   void BindScalarField(Real (*ScalarField)(Real xx));
00158
00170   void BindVectorField(Real (*VectorField)(Real xx));
00171
00183   bool WriteToFile(std::string filename,
00184                    std::string space_name,
00185                    std::string field_name);
00186
00187  private:
00188   FieldNature nature_;
00189
00190   std::vector<Real> discrete_domain_x_;
00191   std::vector<Real> discrete_field_u_;
00192
00193   Real west_bndy_x_;
00194   Real east_bndy_x_;
00195   Real num_cells_x_;
00196   Real delta_x_;
00197 };
00198 }
00199 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_
```

## 17.47 include/mtk_uni_stg_grid_2d.h File Reference

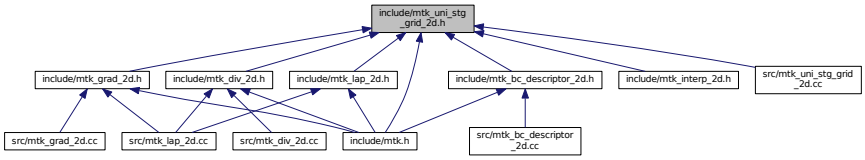
Definition of an 2D uniform staggered grid.

```
#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 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_2d.h.

## 17.48 mtk_uni_stg_grid_2d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_2D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_2D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_enums.h"
00066 #include "mtk_dense_matrix.h"
00067
00068 namespace mtk {
```

```
00069
00079 class UniStgGrid2D {
00080  public:
00082   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid2D &in);
00083
00085   UniStgGrid2D();
00086
00092   UniStgGrid2D(const UniStgGrid2D &grid);
00093
00107   UniStgGrid2D(const Real &west_bndy_x,
00108                const Real &east_bndy_x,
00109                const int &num_cells_x,
00110                const Real &south_bndy_y,
00111                const Real &north_bndy_y,
00112                const int &num_cells_y,
00113                const mtk::FieldNature &nature =
      mtk::SCALAR);
00114
00116   ~UniStgGrid2D();
00117
00123   Real *discrete_domain_x();
00124
00130   Real *discrete_domain_y();
00131
00137   Real *discrete_field();
00138
00146   FieldNature nature() const;
00147
00153   Real west_bndy() const;
00154
00160   Real east_bndy() const;
00161
00167   int num_cells_x() const;
00168
00174   Real delta_x() const;
00175
00181   Real south_bndy() const;
00182
00188   Real north_bndy() const;
00189
00195   int num_cells_y() const;
00196
00202   Real delta_y() const;
00203
00209   void BindScalarField(Real (*ScalarField)(Real xx, Real yy));
00210
00225   void BindVectorField(Real (*VectorFieldPComponent)(Real xx,
      Real yy),
00226                        Real (*VectorFieldQComponent)(Real xx,Real yy));
00227
00240   bool WriteToFile(std::string filename,
00241                    std::string space_name_x,
00242                    std::string space_name_y,
00243                    std::string field_name);
00244
00245  private:
00258   void BindVectorFieldPComponent(
00259     Real (*VectorFieldPComponent)(Real xx, Real yy));
00260
00273   void BindVectorFieldQComponent(
00274     Real (*VectorFieldQComponent)(Real xx, Real yy));
00275
00276
00277   std::vector<Real> discrete_domain_x_;
00278   std::vector<Real> discrete_domain_y_;
00279   std::vector<Real> discrete_field_;
00280
00281   FieldNature nature_;
00282
00283   Real west_bndy_;
00284   Real east_bndy_;
00285   int num_cells_x_;
00286   Real delta_x_;
00287
00288   Real south_bndy_;
00289   Real north_bndy_;
00290   int num_cells_y_;
00291   Real delta_y_;
00292 };
00293 }
00294 #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 CCFLAGS = -Wall -O3
00084
00085 # Flags recommended for debugging code:
00086
00087 CCFLAGS = -Wall -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 ```
00027 $(HOME)/Libraries/
00028 ```
00029
00030 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00031 routines for the internal computation on some of the layers. However, ATLAS
00032 requires both BLAS and LAPACK in order to create their optimized distributions.
00033 Therefore, the following dependencies tree arises:
00034
00035 ### For Linux:
00036
00037 1. LAPACK - Available from: http://www.netlib.org/lapack/
00038   1. BLAS - Available from: http://www.netlib.org/blas/
00039
00040 2. GLPK - Available from: https://www.gnu.org/software/glpk/
00041
00042 3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00043   1. LAPACK - Available from: http://www.netlib.org/lapack/
00044     1. BLAS - Available from: http://www.netlib.org/blas
00045
00046 4. (Optional) Valgrind - Available from: http://valgrind.org/
00047
00048 5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00049
00050 ### For OS X:
00051
00052 1. GLPK - Available from: https://www.gnu.org/software/glpk/
```

```
00053     ____________________________________________________________
00054
00055 ## 3. Installation
00056
00057 ### PART 1. CONFIGURATION OF THE MAKEFILE.
00058
00059 The following steps are required to build and test the MTK. Please use the
00060 accompanying `Makefile.inc` file, which should provide a solid template to
00061 start with. The following command provides help on the options for make:
00062
00063 ```
00064 $ make help
00065 -----
00066 Makefile for the MTK.
00067
00068 Options are:
00069 - all: builds the library, the tests, and examples.
00070 - mtklib: builds the library.
00071 - test: builds the test files.
00072 - example: builds the examples.
00073
00074 - testall: runs all the tests.
00075
00076 - gendoc: generates the documentation for the library.
00077
00078 - clean: cleans all the generated files.
00079 - cleanlib: cleans the generated archive and object files.
00080 - cleantest: cleans the generated tests executables.
00081 - cleanexample: cleans the generated examples executables.
00082 -----
00083 ```
00084
00085 ### PART 2. BUILD THE LIBRARY.
00086
00087 ```
00088 $ make
00089 ```
00090
00091 If successful you'll read (before building the tests and examples):
00092
00093 ```
00094 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
00095 ```
00096
00097 Examples and tests will also be built.
00098     ____________________________________________________________
00099
00100 ## 4. Frequently Asked Questions
00101
00102 Q: Why haven't you guys implemented GBS to build the library?
00103 A: I'm on it as we speak! ;)
00104
00105 Q: Is there any main reference when it comes to the theory on Mimetic Methods?
00106 A: Yes! Check: http://www.csrc.sdsu.edu/mimetic-book
00107
00108 Q: Do I need to generate the documentation myself?
00109 A: You can if you want to... but if you DO NOT want to, just go to our website.
00110     ____________________________________________________________
00111
00112 ## 5. Contact, Support, and Credits
00113
00114 The MTK is developed by researchers and adjuncts to the
00115 [Computational Science Research Center (CSRC)](http://www.csrc.sdsu.edu/)
00116 at [San Diego State University (SDSU)](http://www.sdsu.edu/).
00117
00118 Developers are members of:
00119
00120 1. Mimetic Numerical Methods Research and Development Group.
00121 2. Computational Geoscience Research and Development Group.
00122 3. Ocean Modeling Research and Development Group.
00123
00124 Currently the developers are:
00125
00126 - **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00127 - Jose E. Castillo, Ph.D. - jcastillo at mail dot sdsu dot edu
00128 - Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
00129 - Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
00130 - Angel Boada.
00131 - Johnny Corbino.
00132 - Raul Vargas-Navarro.
00133
```

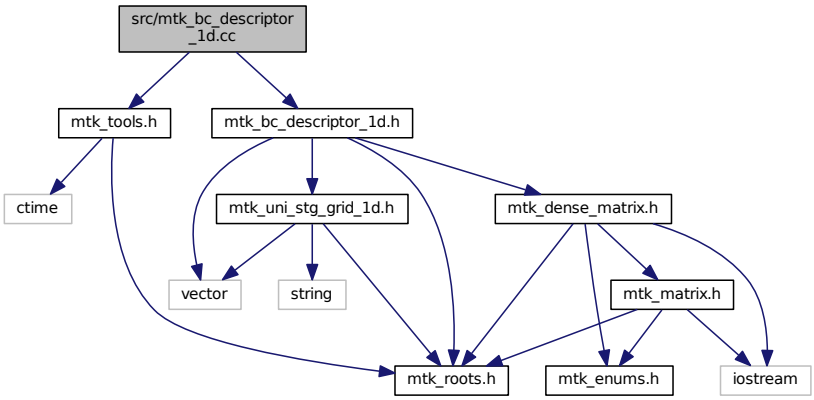
```
00134 Finally, please feel free to contact me with suggestions or corrections:
00135
00136 **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00137
00138 Thanks and happy coding!
```

## 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.
      num_cols(),
00069                       __FILE__, __LINE__, __func__);
00070   mtk::Tools::Prevent(east.size() > (unsigned int) matrix.
      num_cols(),
00071                       __FILE__, __LINE__, __func__);
00072   #endif
00073
00075
00076   for (unsigned int ii = 0; ii < west.size(); ++ii) {
00077     matrix.SetValue(0, ii, west[ii]);
00078   }
00079
00081
00082   for (unsigned int ii = 0; ii < east.size(); ++ii) {
00083     matrix.SetValue(matrix.num_rows() - 1,
00084                     matrix.num_cols() - 1 - ii,
00085                     east[ii]);
00086   }
00087 }
00088
00089 void mtk::BCDescriptor1D::ImposeOnGrid(
      mtk::UniStgGrid1D &grid,
00090                                        const mtk::Real &omega,
00091                                        const mtk::Real &epsilon) {
00092
00093   #if MTK_DEBUG_LEVEL > 0
00094   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00095   #endif
00096
00098
00099   grid.discrete_field_u()[0] = omega;
00100
```

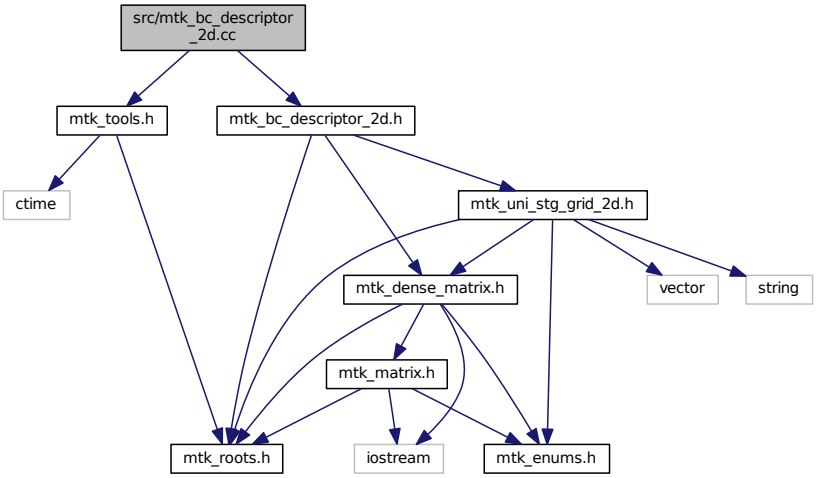
```
00102
00103   grid.discrete_field_u()[grid.num_cells_x() + 2 - 1] = epsilon;
00104 }
```

## 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 implements an interface for the user to specify boundary conditions on 2D 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_2d.cc.

## 17.56 mtk_bc_descriptor_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
```

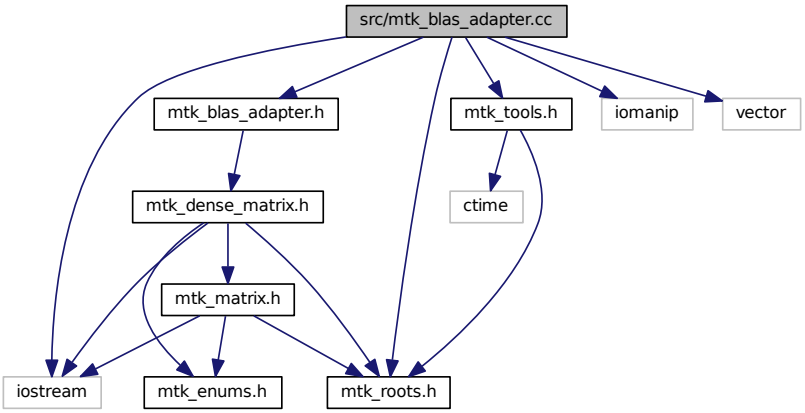
```
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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
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_2d.h"
00060
00061 void mtk::BCDescriptor2D::ImposeOnLaplacianMatrix(
00062     mtk::DenseMatrix &matrix,
00063     mtk::Real (*west)(int ii, int jj),
00064     mtk::Real (*east)(int ii, int jj),
00065     mtk::Real (*south)(int ii, int jj),
00066     mtk::Real (*north)(int ii, int jj)) {
00067
00068   #if MTK_DEBUG_LEVEL > 0
00069   mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00070   mtk::Tools::Prevent(west == nullptr, __FILE__, __LINE__, __func__);
00071   mtk::Tools::Prevent(east == nullptr, __FILE__, __LINE__, __func__);
00072   mtk::Tools::Prevent(south == nullptr, __FILE__, __LINE__, __func__);
00073   mtk::Tools::Prevent(north == nullptr, __FILE__, __LINE__, __func__);
00074   #endif
00075
00076
00077 }
00078
00079 void mtk::BCDescriptor2D::ImposeOnGrid(const
      mtk::UniStgGrid2D &grid,
00080     mtk::Real (*west)(mtk::Real xx, mtk::Real yy),
00081     mtk::Real (*east)(mtk::Real xx, mtk::Real yy),
00082     mtk::Real (*south)(mtk::Real xx, mtk::Real yy),
00083     mtk::Real (*north)(mtk::Real xx, mtk::Real yy)) {
00084
00085   #if MTK_DEBUG_LEVEL > 0
00086   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00087   mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00088   mtk::Tools::Prevent(west == nullptr, __FILE__, __LINE__, __func__);
00089   mtk::Tools::Prevent(east == nullptr, __FILE__, __LINE__, __func__);
00090   mtk::Tools::Prevent(south == nullptr, __FILE__, __LINE__, __func__);
00091   mtk::Tools::Prevent(north == nullptr, __FILE__, __LINE__, __func__);
00092   #endif
00093
00094
00095 }
```

## 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**

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

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
00048 5. Neither the name of the copyright holder nor the names of its contributors
00049 may be used to endorse or promote products derived from this software without
00050 specific prior written permission.
00051
00052 The copyright holders provide no reassurances that the source code provided does
00053 not infringe any patent, copyright, or any other intellectual property rights of
00054 third parties. The copyright holders disclaim any liability to any recipient for
00055 claims brought against recipient by any third party for infringement of that
00056 parties intellectual property rights.
00057
00058 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00059 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
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 dnrm2_(int *n, double *x, int *incx);
00098 #else
00099
00112 float snrm2_(int *n, float *x, int *incx);
00113 #endif
00114
00115 #ifdef MTK_PRECISION_DOUBLE
00116
00135 void daxpy_(int *n, double *da, double *dx, int *incx, double *dy, int *incy);
00136 #else
00137
00156 void saxpy_(int *n, float *sa, float *sx, int *incx, float *sy, int *incy);
00157 #endif
00158
00159 #ifdef MTK_PRECISION_DOUBLE
00160
00188 void dgemv_(char *trans,
00189             int *m,
00190             int *n,
00191             double *alpha,
00192             double *a,
00193             int *lda,
00194             double *x,
00195             int *incx,
00196             double *beta,
00197             double *y,
00198             int *incy);
00199 #else
00200
00228 void sgemv_(char *trans,
00229             int *m,
00230             int *n,
00231             float *alpha,
00232             float *a,
00233             int *lda,
00234             float *x,
00235             int *incx,
00236             float *beta,
00237             float *y,
00238             int *incy);
00239 #endif
00240
00241 #ifdef MTK_PRECISION_DOUBLE
00242
00267 void dgemm_(char *transa,
00268             char* transb,
00269             int *m,
00270             int *n,
00271             int *k,
00272             double *alpha,
00273             double *a,
00274             int *lda,
00275             double *b,
00276             int *ldb,
00277             double *beta,
00278             double *c,
00279             int *ldc);
00280 }
00281 #else
00282
00307 void sgemm_(char *transa,
00308             char* transb,
00309             int *m,
00310             int *n,
00311             int *k,
00312             double *alpha,
00313             double *a,
00314             int *lda,
00315             double *b,aamm
00316             int *ldb,
00317             double *beta,
00318             double *c,
00319             int *ldc);
00320 }
00321 #endif
```

```
00322 }
00323
00324 mtk::Real mtk::BLASAdapter::RealNRM2(Real *in, int &in_length) {
00325
00326   #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 dnrm2_(&in_length, in, &incx);
00334   #else
00335   return snrm2_(&in_length, in, &incx);
00336   #endif
00337 }
00338
00339 void mtk::BLASAdapter::RealAXPY(mtk::Real alpha,
00340                                 mtk::Real *xx,
00341                                 mtk::Real *yy,
00342                                 int &in_length) {
00343
00344   #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(
      mtk::Real *computed,
00359                                         mtk::Real *known,
00360                                         int length) {
00361
00362   #if MTK_DEBUG_LEVEL > 0
00363   mtk::Tools::Prevent(computed == nullptr, __FILE__, __LINE__, __func__);
00364   mtk::Tools::Prevent(known == nullptr, __FILE__, __LINE__, __func__);
00365   #endif
00366
00367   mtk::Real norm_2_computed{mtk::BLASAdapter::RealNRM2(known, length)};
00368
00369   mtk::Real alpha{-mtk::kOne};
00370
00371   mtk::BLASAdapter::RealAXPY(alpha, known, computed, length);
00372
00373   mtk::Real norm_2_difference{mtk::BLASAdapter::RealNRM2(computed,
      length)};
00374
00375   return norm_2_difference/norm_2_computed;
00376 }
00377
00378 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00379                                    mtk::DenseMatrix &aa,
00380                                    mtk::Real *xx,
00381                                    mtk::Real &beta,
00382                                    mtk::Real *yy) {
00383
00384   // Make sure input matrices are row-major ordered.
00385
00386   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00387     aa.OrderRowMajor();
00388   }
00389
00390   char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00391
00392   int mm{aa.num_rows()};                  // Rows of aa.
00393   int nn{aa.num_cols()};                  // Columns of aa.
00394   int lda{(aa.matrix_properties()).ld()}; // Leading dimension.
00395   int incx{1};                            // Increment of values in x.
00396   int incy{1};                            // Increment of values in y.
00397
00398   std::swap(mm,nn);
00399   #ifdef MTK_PRECISION_DOUBLE
```

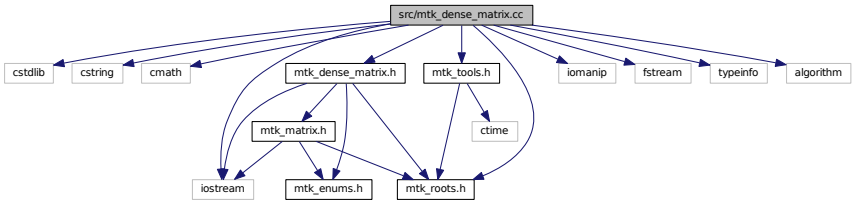
```
00400   dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00401          xx, &incx, &beta, yy, &incy);
00402   #else
00403   sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00404         xx, &incx, &beta, yy, &incy);
00405   #endif
00406   std::swap(mm,nn);
00407 }
00408
00409 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
      mtk::DenseMatrix &aa,
00410                                                mtk::DenseMatrix &bb) {
00411
00412   #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 /*
00014 Copyright (C) 2015, Computational Science Research Center, San Diego State
00015 University. All rights reserved.
00016
00017 Redistribution and use in source and binary forms, with or without modification,
00018 are permitted provided that the following conditions are met:
00019
00020 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00021 and a copy of the modified files should be reported once modifications are
00022 completed, unless these modifications are made through the project's GitHub
00023 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00024 should be developed and included in any deliverable.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions in binary form must reproduce the above copyright notice,
00030 this list of conditions and the following disclaimer in the documentation and/or
00031 other materials provided with the distribution.
00032
00033 4. Usage of the binary form on proprietary applications shall require explicit
00034 prior written permission from the the copyright holders, and due credit should
00035 be given to the copyright holders.
00036
```

```
00037 5. Neither the name of the copyright holder nor the names of its contributors
00038 may be used to endorse or promote products derived from this software without
00039 specific prior written permission.
00040
00041 The copyright holders provide no reassurances that the source code provided does
00042 not infringe any patent, copyright, or any other intellectual property rights of
00043 third parties. The copyright holders disclaim any liability to any recipient for
00044 claims brought against recipient by any third party for infringement of that
00045 parties intellectual property rights.
00046
00047 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00048 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00049 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00050 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00051 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00052 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00053 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #include <cstdlib>
00060 #include <cstring>
00061 #include <cmath>
00062
00063 #include <iostream>
00064 #include <iomanip>
00065 #include <fstream>
00066
00067 #include <typeinfo>
00068
00069 #include <algorithm>
00070
00071 #include "mtk_roots.h"
00072 #include "mtk_dense_matrix.h"
00073 #include "mtk_tools.h"
00074
00075 namespace mtk {
00076
00077 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00078
00079   int mm{in.matrix_properties_.num_rows()};  // Auxiliary.
00080   int nn{in.matrix_properties_.num_cols()};  // Auxiliary.
00081
00082   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00083     std::swap(mm, nn);
00084   }
00085   for (int ii = 0; ii < mm; ii++) {
00086     int offset{ii*nn};
00087     for (int jj = 0; jj < nn; jj++) {
00088       mtk::Real value = in.data_[offset + jj];
00089       stream << std::setw(9) << value;
00090     }
00091     stream << std::endl;
00092   }
00093   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00094     std::swap(mm, nn);
00095   }
00096   return stream;
00097 }
00098 }
00099
00100 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
      mtk::DenseMatrix &in) {
00101
00102   if(this == &in) {
00103     return *this;
00104   }
00105
00106   matrix_properties_.set_storage(in.
      matrix_properties_.storage());
00107
00108   matrix_properties_.set_ordering(in.
      matrix_properties_.ordering());
00109
00110   auto aux = in.matrix_properties_.num_rows();
00111   matrix_properties_.set_num_rows(aux);
00112
```

```
00113   aux = in.matrix_properties().num_cols();
00114   matrix_properties_.set_num_cols(aux);
00115
00116   aux = in.matrix_properties().num_zero();
00117   matrix_properties_.set_num_zero(aux);
00118
00119   aux = in.matrix_properties().num_null();
00120   matrix_properties_.set_num_null(aux);
00121
00122   auto num_rows = matrix_properties_.num_rows();
00123   auto num_cols = matrix_properties_.num_cols();
00124
00125   delete [] data_;
00126
00127   try {
00128     data_ = new mtk::Real[num_rows*num_cols];
00129   } catch (std::bad_alloc &memory_allocation_exception) {
00130     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00131       std::endl;
00132     std::cerr << memory_allocation_exception.what() << std::endl;
00133   }
00134   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*
      num_cols);
00135
00136   std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00137
00138   return *this;
00139 }
00140
00141 bool mtk::DenseMatrix::operator ==(const
      DenseMatrix &in) {
00142
00143   bool ans{true};
00144
00145   auto mm = in.num_rows();
00146   auto nn = in.num_cols();
00147
00148   if (mm != matrix_properties_.num_rows() ||
00149       nn != matrix_properties_.num_cols()) {
00150     return false;
00151   }
00152
00153   for (int ii = 0; ii < mm && ans; ++ii) {
00154     for (int jj = 0; jj < nn && ans; ++jj) {
00155       ans = ans &&
00156         abs(data_[ii*nn + jj] - in.data()[ii*nn + jj]) <
      mtk::kDefaultTolerance;
00157     }
00158   }
00159   return ans;
00160 }
00161
00162 mtk::DenseMatrix::DenseMatrix(): data_(nullptr) {
00163
00164   matrix_properties_.set_storage(mtk::DENSE);
00165   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00166 }
00167
00168 mtk::DenseMatrix::DenseMatrix(const
      mtk::DenseMatrix &in) {
00169
00170   matrix_properties_.set_storage(in.matrix_properties_.storage());
00171
00172   matrix_properties_.set_ordering(in.matrix_properties_.
      ordering());
00173
00174   auto aux = in.matrix_properties_.num_rows();
00175   matrix_properties_.set_num_rows(aux);
00176
00177   aux = in.matrix_properties().num_cols();
00178   matrix_properties_.set_num_cols(aux);
00179
00180   aux = in.matrix_properties().num_zero();
00181   matrix_properties_.set_num_zero(aux);
00182
00183   aux = in.matrix_properties().num_null();
00184   matrix_properties_.set_num_null(aux);
00185
00186   auto num_rows = in.matrix_properties_.num_rows();
00187   auto num_cols = in.matrix_properties_.num_cols();
00188
```

```
00189   try {
00190     data_ = new mtk::Real[num_rows*num_cols];
00191   } catch (std::bad_alloc &memory_allocation_exception) {
00192     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00193       std::endl;
00194     std::cerr << memory_allocation_exception.what() << std::endl;
00195   }
00196   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00197
00198   std::copy(in.data_,in.data_ + num_rows*num_cols,data_);
00199 }
00200
00201 mtk::DenseMatrix::DenseMatrix(const int &num_rows, const int &num_cols) {
00202
00203   #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 *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
00314   delete[] data_;
00315   data_ = nullptr;
00316 }
00317
00318 mtk::Matrix mtk::DenseMatrix::matrix_properties() const {
00319
00320   return matrix_properties_;
00321 }
00322
00323 void mtk::DenseMatrix::SetOrdering(
    mtk::MatrixOrdering oo) {
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 {
00334
00335   return matrix_properties_.num_rows();
00336 }
00337
00338 int mtk::DenseMatrix::num_cols() const {
00339
00340   return matrix_properties_.num_cols();
00341 }
00342
00343 mtk::Real* mtk::DenseMatrix::data() const {
00344
00345   return data_;
00346 }
00347
00348 mtk::Real mtk::DenseMatrix::GetValue(
```

```
00349     const int &mm,
00350     const int &nn) const {
00351
00352   #if MTK_DEBUG_LEVEL > 0
00353   mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00354   mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00355   #endif
00356
00357   return data_[mm*matrix_properties_.num_cols() + nn];
00358 }
00359
00360 void  mtk::DenseMatrix::SetValue(
00361     const int &mm,
00362     const int &nn,
00363     const mtk::Real &val) {
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
00376
00377   mtk::Real *data_transposed{}; // Buffer.
00378
00379   int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00380   int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00381
00382   try {
00383     data_transposed = new mtk::Real[mm*nn];
00384   } catch (std::bad_alloc &memory_allocation_exception) {
00385     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00386       std::endl;
00387     std::cerr << memory_allocation_exception.what() << std::endl;
00388   }
00389   memset(data_transposed,
00390          mtk::kZero,
00391          sizeof(data_transposed[0])*mm*nn);
00392
00393   // Assign the values to their transposed position.
00394   for (auto ii = 0; ii < mm; ++ii) {
00395     for (auto jj = 0; jj < nn; ++jj) {
00396       data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00397     }
00398   }
00399
00400   // Swap pointers.
00401   auto tmp = data_; // Temporal holder.
00402   data_ = data_transposed;
00403   delete [] tmp;
00404   tmp = nullptr;
00405
00406   matrix_properties_.set_num_rows(nn);
00407   matrix_properties_.set_num_cols(mm);
00408 }
00409
00410 void mtk::DenseMatrix::OrderRowMajor() {
00411
00412   if (matrix_properties_.ordering() == mtk::COL_MAJOR) {
00413
00415
00416     mtk::Real *data_transposed{}; // Buffer.
00417
00418     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00419     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00420
00421     try {
00422       data_transposed = new mtk::Real[mm*nn];
00423     } catch (std::bad_alloc &memory_allocation_exception) {
00424       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00425         std::endl;
00426       std::cerr << memory_allocation_exception.what() << std::endl;
00427     }
00428     memset(data_transposed,
00429            mtk::kZero,
00430            sizeof(data_transposed[0])*mm*nn);
00431
```

```
00432     // Assign the values to their transposed position.
00433     std::swap(mm, nn);
00434     for (auto ii = 0; ii < mm; ++ii) {
00435       for (auto jj = 0; jj < nn; ++jj) {
00436         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00437       }
00438     }
00439     std::swap(mm, nn);
00440 
00441     // Swap pointers.
00442     auto tmp = data_; // Temporal holder.
00443     data_ = data_transposed;
00444     delete [] tmp;
00445     tmp = nullptr;
00446 
00447     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00448   }
00449 }
00450 
00451 void mtk::DenseMatrix::OrderColMajor() {
00452 
00453   if (matrix_properties_.ordering() == ROW_MAJOR) {
00454 
00456 
00457     mtk::Real *data_transposed{}; // Buffer.
00458 
00459     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00460     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00461 
00462     try {
00463       data_transposed = new mtk::Real[mm*nn];
00464     } catch (std::bad_alloc &memory_allocation_exception) {
00465       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00466         std::endl;
00467       std::cerr << memory_allocation_exception.what() << std::endl;
00468     }
00469     memset(data_transposed,
00470           mtk::kZero,
00471           sizeof(data_transposed[0])*mm*nn);
00472 
00473     // Assign the values to their transposed position.
00474     for (auto ii = 0; ii < mm; ++ii) {
00475       for (auto jj = 0; jj < nn; ++jj) {
00476         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00477       }
00478     }
00479 
00480     // Swap pointers.
00481     auto tmp = data_; // Temporal holder.
00482     data_ = data_transposed;
00483     delete [] tmp;
00484     tmp = nullptr;
00485 
00486     matrix_properties_.set_ordering(mtk::COL_MAJOR);
00487   }
00488 }
00489 
00490 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
     mtk::DenseMatrix &aa,
00491                                         const mtk::DenseMatrix &bb) {
00492 
00493   int row_offset{}; // Offset for rows.
00494   int col_offset{}; // Offset for rows.
00495 
00496   mtk::Real aa_factor{}; // Used in computation.
00497 
00498   // Auxiliary variables:
00499   auto aux1 = aa.matrix_properties_.num_rows()*bb.
     matrix_properties_.num_rows();
00500   auto aux2 = aa.matrix_properties_.num_cols()*bb.
     matrix_properties_.num_cols();
00501 
00502   mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00503 
00504   int kk_num_cols{output.matrix_properties_.num_cols()}; // Aux.
00505 
00506   auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00507   auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00508   auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00509   auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00510 
```

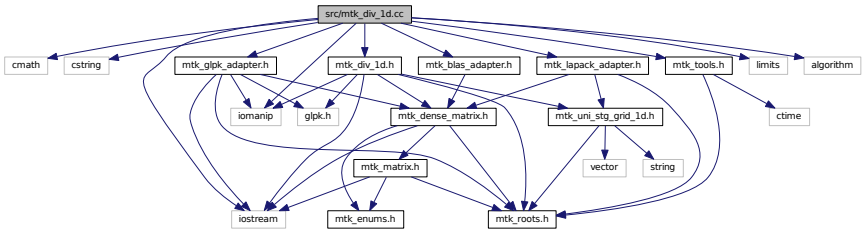
```
00511   for (auto ii = 0; ii < mm; ++ii) {
00512     row_offset = ii*pp;
00513     for (auto jj = 0; jj < nn; ++jj) {
00514       col_offset = jj*qq;
00515       aa_factor = aa.data_[ii*nn + jj];
00516       for (auto ll = 0; ll < pp; ++ll) {
00517         for (auto oo = 0; oo < qq; ++oo) {
00518           auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00519           output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00520         }
00521       }
00522     }
00523   }
00524
00525   output.matrix_properties_.set_storage(mtk::DENSE);
00526   output.matrix_properties_.set_ordering(
      mtk::ROW_MAJOR);
00527
00528   return output;
00529 }
00530
00531 bool mtk::DenseMatrix::WriteToFile(std::string filename) {
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**

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

**Todo** Overload ostream operator as in mtk::Lap1D.

**Todo** Implement creation of ■ w. mtk::BLASAdapter.

Definition in file mtk_div_1d.cc.

## 17.62 mtk_div_1d.cc

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

```
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
00039 5. Neither the name of the copyright holder nor the names of its contributors
00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
00042
00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00050 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
00075 #include "mtk_div_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Div1D &in) {
00080
00082
00083   stream << "divergence_[0] = " << std::setw(9) << in.divergence_[0] <<
00084     std::endl;
00085
00087
00088   stream << "divergence_[1:" << in.order_accuracy_ << "] = ";
00089   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00090     stream << std::setw(9) << in.divergence_[ii] << " ";
00091   }
00092   stream << std::endl;
00093
00094   if (in.order_accuracy_ > 2) {
00095
00097
00098     stream << "divergence_[" << in.order_accuracy_ + 1 << ":" <<
00099       2*in.order_accuracy_ << "] = ";
00100     for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00101       stream << std::setw(9) << in.divergence_[ii] << " ";
00102     }
00103     stream << std::endl;
00104
00106
00107     auto offset = (2*in.order_accuracy_ + 1);
00108     int mm{};
00109     for (auto ii = 0; ii < in.dim_null_; ++ii) {
00110       stream << "divergence_[" << offset + mm << ":" <<
00111         offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
```

```
00113         auto value = in.divergence_[offset + mm];
00114         stream << std::setw(9) << value << " ";
00115         ++mm;
00116       }
00117       stream << std::endl;
00118     }
00119   }
00120
00121   return stream;
00122 }
00123 }
00124
00125 mtk::Div1D::Div1D():
00126   order_accuracy_(mtk::kDefaultOrderAccuracy),
00127   dim_null_(),
00128   num_bndy_coeffs_(),
00129   divergence_length_(),
00130   minrow_(),
00131   row_(),
00132   coeffs_interior_(),
00133   prem_apps_(),
00134   weights_crs_(),
00135   weights_cbs_(),
00136   mim_bndy_(),
00137   divergence_(),
00138   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00139
00140 mtk::Div1D::Div1D(const Div1D &div):
00141   order_accuracy_(div.order_accuracy_),
00142   dim_null_(div.dim_null_),
00143   num_bndy_coeffs_(div.num_bndy_coeffs_),
00144   divergence_length_(div.divergence_length_),
00145   minrow_(div.minrow_),
00146   row_(div.row_),
00147   coeffs_interior_(div.coeffs_interior_),
00148   prem_apps_(div.prem_apps_),
00149   weights_crs_(div.weights_crs_),
00150   weights_cbs_(div.weights_cbs_),
00151   mim_bndy_(div.mim_bndy_),
00152   divergence_(div.divergence_),
00153   mimetic_threshold_(div.mimetic_threshold_) {}
00154
00155 mtk::Div1D::~Div1D() {
00156
00157   delete[] coeffs_interior_;
00158   coeffs_interior_ = nullptr;
00159
00160   delete[] prem_apps_;
00161   prem_apps_ = nullptr;
00162
00163   delete[] weights_crs_;
00164   weights_crs_ = nullptr;
00165
00166   delete[] weights_cbs_;
00167   weights_cbs_ = nullptr;
00168
00169   delete[] mim_bndy_;
00170   mim_bndy_ = nullptr;
00171
00172   delete[] divergence_;
00173   divergence_ = nullptr;
00174 }
00175
00176 bool mtk::Div1D::ConstructDiv1D(int order_accuracy,
00177                                 mtk::Real mimetic_threshold) {
00178
00179   #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
00197
00198   bool abort_construction = ComputeStencilInteriorGrid();
00199
00200   #if MTK_DEBUG_LEVEL > 0
00201   if (!abort_construction) {
00202     std::cerr << "Could NOT complete stage 1." << std::endl;
00203     std::cerr << "Exiting..." << std::endl;
00204     return false;
00205   }
00206   #endif
00207
00208   // At this point, we already have the values for the interior stencil stored
00209   // in the coeffs_interior_ array.
00210
00211   // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00212   // approximation at the boundary, thus it has no weights. For this case, the
00213   // dimension of the null-space of the Vandermonde matrices used to compute the
00214   // approximating coefficients at the boundary is 0. Ergo, we compute this
00215   // number first and then decide if we must compute anything at the boundary.
00216
00217   dim_null_ = order_accuracy_/2 - 1;
00218
00219   if (dim_null_ > 0) {
00220
00221     #ifdef MTK_PRECISION_DOUBLE
00222     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00223     #else
00224     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00225     #endif
00226
00228
00229     // For this we will follow recommendations given in:
00230     //
00231     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00232     //
00233     // We will compute the QR Factorization of the transpose, as in the
00234     // following (MATLAB) pseudo-code:
00235     //
00236     // [Q,R] = qr(V'); % Full QR as defined in
00237     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00238     //
00239     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00240     //
00241     // However, given the nature of the Vandermonde matrices we've just
00242     // computed, they all posses the same null-space. Therefore, we impose the
00243     // convention of computing the null-space of the first Vandermonde matrix
00244     // (west boundary).
00245
00246     abort_construction = ComputeRationalBasisNullSpace();
00247
00248     #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
00257
00258     abort_construction = ComputePreliminaryApproximations();
00259
00260     #if MTK_DEBUG_LEVEL > 0
00261     if (!abort_construction) {
00262       std::cerr << "Could NOT complete stage 2.2." << std::endl;
00263       std::cerr << "Exiting..." << std::endl;
00264       return false;
00265     }
00266     #endif
00267
00269
00270     abort_construction = ComputeWeights();
00271
00272     #if MTK_DEBUG_LEVEL > 0
00273     if (!abort_construction) {
00274       std::cerr << "Could NOT complete stage 2.3." << std::endl;
00275       std::cerr << "Exiting..." << std::endl;
00276       return false;
00277     }
00278     #endif
```

```
00279
00281
00282     abort_construction = ComputeStencilBoundaryGrid();
00283
00284     #if MTK_DEBUG_LEVEL > 0
00285     if (!abort_construction) {
00286       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00287       std::cerr << "Exiting..." << std::endl;
00288       return false;
00289     }
00290     #endif
00291
00292   } // End of: if (dim_null_ > 0);
00293
00295
00296   // Once we have the following three collections of data:
00297   //   (a) the coefficients for the interior,
00298   //   (b) the coefficients for the boundary (if it applies),
00299   //   (c) and the weights (if it applies),
00300   // we will store everything in the output array:
00301
00302   abort_construction = AssembleOperator();
00303
00304   #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
00317   return num_bndy_coeffs_;
00318 }
00319
00320 mtk::Real *mtk::Div1D::coeffs_interior() const {
00321
00322   return coeffs_interior_;
00323 }
00324
00325 mtk::Real *mtk::Div1D::weights_crs() const {
00326
00327   return weights_crs_;
00328 }
00329
00330 mtk::Real *mtk::Div1D::weights_cbs() const {
00331
00332
00333   return weights_cbs_;
00334 }
00335
00336 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00337
00338   mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00339
00340   auto counter = 0;
00341   for (auto ii = 0; ii < dim_null_; ++ii) {
00342     for(auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00343       xx.SetValue(ii,jj, divergence_[2*order_accuracy_ + 1 + counter]);
00344       counter++;
00345     }
00346   }
00347
00348   return xx;
00349 }
00350
00351 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) {
00352
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
00371
00372   auto ee_index = 0;
00373   for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00374     auto cc = 0;
00375     for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00376       if( cc >= elements_per_row) {
00377         out.SetValue(ii, jj, mtk::kZero);
00378       } else {
00379         out.SetValue(ii,jj, mim_bndy_[ee_index++]*inv_delta_x);
00380         cc++;
00381       }
00382     }
00383   }
00384
00386
00387   for (auto ii = num_extra_rows + 1;
00388        ii < dd_num_rows - num_extra_rows - 1; ii++) {
00389     auto jj = ii - num_extra_rows - 1;
00390     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00391       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00392     }
00393   }
00394
00396
00397   ee_index = 0;
00398   for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--) {
00399     auto cc = 0;
00400     for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00401       if( cc >= elements_per_row) {
00402         out.SetValue(ii,jj,0.0);
00403       } else {
00404         out.SetValue(ii,jj,-mim_bndy_[ee_index++]*inv_delta_x);
00405         cc++;
00406       }
00407      }
00408   }
00409
00410   return out;
00411 }
00412
00413 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00414
00416
00417   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00418
00419   try {
00420     pp = new mtk::Real[order_accuracy_];
00421   } catch (std::bad_alloc &memory_allocation_exception) {
00422     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00423       std::endl;
00424     std::cerr << memory_allocation_exception.what() << std::endl;
00425   }
00426   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00427
00428   #ifdef MTK_PRECISION_DOUBLE
00429   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00430   #else
00431   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00432   #endif
00433
00434   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00435     pp[ii] = pp[ii - 1] + mtk::kOne;
00436   }
00437
00438   #if MTK_DEBUG_LEVEL > 0
00439   std::cout << "pp =" << std::endl;
00440   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00441     std::cout << std::setw(12) << pp[ii];
00442   }
00443   std::cout << std::endl << std::endl;
00444   #endif
00445
```

```
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
00461
00462   try {
00463     coeffs_interior_ = new mtk::Real[order_accuracy_];
00464   } catch (std::bad_alloc &memory_allocation_exception) {
00465     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00466       std::endl;
00467     std::cerr << memory_allocation_exception.what() << std::endl;
00468   }
00469   memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00470
00471   coeffs_interior_[1] = mtk::kOne;
00472
00473   #if MTK_DEBUG_LEVEL > 0
00474   std::cout << "oo =" << std::endl;
00475   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00476     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00477   }
00478   std::cout << std::endl;
00479   #endif
00480
00482
00483   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00484                                                 coeffs_interior_)};
00485
00486   #if MTK_DEBUG_LEVEL > 0
00487   if (!info) {
00488     std::cout << "System solved! Interior stencil attained!" << std::endl;
00489     std::cout << std::endl;
00490   }
00491   else {
00492     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00493     std::cerr << "Exiting..." << std::endl;
00494     return false;
00495   }
00496   #endif
00497
00498   #if MTK_DEBUG_LEVEL > 0
00499   std::cout << "coeffs_interior_ =" << std::endl;
00500   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00501     std::cout << std::setw(12) << coeffs_interior_[ii];
00502   }
00503   std::cout << std::endl << std::endl;
00504   #endif
00505
00506   delete [] pp;
00507   pp = nullptr;
00508
00509   return true;
00510 }
00511
00512 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00513
00514   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00515
00517
00518   try {
00519     gg = new mtk::Real[num_bndy_coeffs_];
00520   } catch (std::bad_alloc &memory_allocation_exception) {
00521     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00522       std::endl;
00523     std::cerr << memory_allocation_exception.what() << std::endl;
00524   }
00525   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00526
00527   #ifdef MTK_PRECISION_DOUBLE
00528   gg[0] = -1.0/2.0;
00529   #else
00530   gg[0] = -1.0f/2.0f;
```

```
00531   #endif
00532   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00533     gg[ii] = gg[ii - 1] + mtk::kOne;
00534   }
00535
00536   #if MTK_DEBUG_LEVEL > 0
00537   std::cout << "gg =" << std::endl;
00538   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00539     std::cout << std::setw(12) << gg[ii];
00540   }
00541   std::cout << std::endl << std::endl;
00542   #endif
00543
00545
00546   bool tran{true}; // Should I transpose the Vandermonde matrix.
00547
00548   mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00549
00550   #if MTK_DEBUG_LEVEL > 0
00551   std::cout << "vv_west_t =" << std::endl;
00552   std::cout << vv_west_t << std::endl;
00553   #endif
00554
00556
00557   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (vv_west_t));
00558
00559   #if MTK_DEBUG_LEVEL > 0
00560   std::cout << "QQ^T = " << std::endl;
00561   std::cout << qq_t << std::endl;
00562   #endif
00563
00565
00566   int KK_num_rows_{num_bndy_coeffs_};
00567   int KK_num_cols_{dim_null_};
00568
00569   mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00570
00571   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00572     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00573       KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00574           qq_t.data()[ii*num_bndy_coeffs_ + jj];
00575     }
00576   }
00577
00578   #if MTK_DEBUG_LEVEL > 0
00579   std::cout << "KK =" << std::endl;
00580   std::cout << KK << std::endl;
00581   std::cout << "KK.num_rows() = " << KK.num_rows() << std::endl;
00582   std::cout << "KK.num_cols() = " << KK.num_cols() << std::endl;
00583   std::cout << std::endl;
00584   #endif
00585
00587
00588   // Scale thus requesting that the last entries of the attained basis for the
00589   // null-space, adopt the pattern we require.
00590   // Essentially we will implement the following MATLAB pseudo-code:
00591   //  scalers = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00592   //  SK = KK*scalers
00593   // where SK is the scaled null-space.
00594
00595   // In this point, we almost have all the data we need correctly allocated
00596   // in memory. We will create the matrix II_, and elements we wish to scale in
00597   // the KK array. Using the concept of the leading dimension, we could just
00598   // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00599   // GET how does it work. So I will just create a matrix with the content of
00600   // this array that we need, solve for the scalers and then scale the
00601   // whole KK:
00602
00603   // We will then create memory for that sub-matrix of KK (SUBK).
00604
00605   mtk::DenseMatrix SUBK(dim_null_,dim_null_);
00606
00607   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00608     for (auto jj = 0; jj < dim_null_; ++jj) {
00609       SUBK.data()[(ii - (num_bndy_coeffs_ - dim_null_))*dim_null_ + jj] =
00610           KK.data()[ii*dim_null_ + jj];
00611     }
00612   }
00613
00614   #if MTK_DEBUG_LEVEL > 0
```

```
00615   std::cout << "SUBK =" << std::endl;
00616   std::cout << SUBK << std::endl;
00617   #endif
00618
00619   SUBK.Transpose();
00620
00621   #if MTK_DEBUG_LEVEL > 0
00622   std::cout << "SUBK^T =" << std::endl;
00623   std::cout << SUBK << std::endl;
00624   #endif
00625
00626   bool padded{false};
00627   tran = false;
00628
00629   mtk::DenseMatrix II(dim_null_, padded, tran);
00630
00631   #if MTK_DEBUG_LEVEL > 0
00632   std::cout << "II =" << std::endl;
00633   std::cout << II << std::endl;
00634   #endif
00635
00636   // Solve the system to compute the scalers.
00637   // An example of the system to solve, for k = 8, is:
00638   //
00639   // SUBK*scalers = II_ or
00640   //
00641   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00642   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00643   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00644   //
00645   // Notice this is a nrhs = 3 system.
00646   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00647   // will be stored in the created identity matrix.
00648   // Let us first transpose SUBK (because of LAPACK):
00649
00650   int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00651
00652   #if MTK_DEBUG_LEVEL > 0
00653   if (!info) {
00654     std::cout << "System successfully solved!" <<
00655       std::endl;
00656   } else {
00657     std::cerr << "Something went wrong solving system! info = " << info <<
00658       std::endl;
00659     std::cerr << "Exiting..." << std::endl;
00660     return false;
00661   }
00662   std::cout << std::endl;
00663   #endif
00664
00665   #if MTK_DEBUG_LEVEL > 0
00666   std::cout << "Computed scalers:" << std::endl;
00667   std::cout << II << std::endl;
00668   #endif
00669
00670   // Multiply the two matrices to attain a scaled basis for null-space.
00671
00672   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00673
00674   #if MTK_DEBUG_LEVEL > 0
00675   std::cout << "Rational basis for the null-space:" << std::endl;
00676   std::cout << rat_basis_null_space_ << std::endl;
00677   #endif
00678
00679   // At this point, we have a rational basis for the null-space, with the
00680   // pattern we need! :)
00681
00682   delete [] gg;
00683   gg = nullptr;
00684
00685   return true;
00686 }
00687
00688 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00689
00691
00692   mtk::Real *gg{}; // Generator vector for the first approximation.
00693
00694   try {
00695     gg = new mtk::Real[num_bndy_coeffs_];
00696   } catch (std::bad_alloc &memory_allocation_exception) {
```

```
00697     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00698 std::endl;
00699     std::cerr << memory_allocation_exception.what() << std::endl;
00700   }
00701   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00702
00703   #ifdef MTK_PRECISION_DOUBLE
00704   gg[0] = -1.0/2.0;
00705   #else
00706   gg[0] = -1.0f/2.0f;
00707   #endif
00708   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00709     gg[ii] = gg[ii - 1] + mtk::kOne;
00710   }
00711
00712   #if MTK_DEBUG_LEVEL > 0
00713   std::cout << "gg0 =" << std::endl;
00714   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00715     std::cout << std::setw(12) << gg[ii];
00716   }
00717   std::cout << std::endl << std::endl;
00718   #endif
00719
00720   // Allocate 2D array to store the collection of preliminary approximations.
00721   try {
00722     prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
00723   } catch (std::bad_alloc &memory_allocation_exception) {
00724     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00725 std::endl;
00726     std::cerr << memory_allocation_exception.what() << std::endl;
00727   }
00728   memset(prem_apps_,
00729          mtk::kZero,
00730          sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00731
00733
00734   for (auto ll = 0; ll < dim_null_; ++ll) {
00735
00736     // Re-check new generator vector for every iteration except for the first.
00737     #if MTK_DEBUG_LEVEL > 0
00738     if (ll > 0) {
00739       std::cout << "gg" << ll << " =" << std::endl;
00740       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00741         std::cout << std::setw(12) << gg[ii];
00742       }
00743       std::cout << std::endl << std::endl;
00744     }
00745     #endif
00746
00748
00749     bool transpose{false};
00750
00751     mtk::DenseMatrix AA_(gg,
00752                          num_bndy_coeffs_, order_accuracy_ + 1,
00753                          transpose);
00754
00755     #if MTK_DEBUG_LEVEL > 0
00756     std::cout << "AA_" << ll << " =" << std::endl;
00757     std::cout << AA_ << std::endl;
00758     #endif
00759
00761
00762     mtk::Real *ob{};
00763
00764     auto ob_ld = num_bndy_coeffs_;
00765
00766     try {
00767       ob = new mtk::Real[ob_ld];
00768     } catch (std::bad_alloc &memory_allocation_exception) {
00769       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00770         std::endl;
00771       std::cerr << memory_allocation_exception.what() << std::endl;
00772     }
00773     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00774
00775     ob[1] = mtk::kOne;
00776
00777     #if MTK_DEBUG_LEVEL > 0
00778     std::cout << "ob = " << std::endl << std::endl;
00779     for (auto ii = 0; ii < ob_ld; ++ii) {
00780       std::cout << std::setw(12) << ob[ii] << std::endl;
```

```
00781     }
00782     std::cout << std::endl;
00783     #endif
00784
00786
00787     // However, this is an under-determined system of equations. So we can not
00788     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00789     // our LAPACKAdapter class.
00790
00791     int info_{
00792       mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
      ob, ob_ld)};
00793
00794     #if MTK_DEBUG_LEVEL > 0
00795     if (!info_) {
00796       std::cout << "System successfully solved!" << std::endl << std::endl;
00797     } else {
00798       std::cerr << "Error solving system! info = " << info_ << std::endl;
00799     }
00800     #endif
00801
00802     #if MTK_DEBUG_LEVEL > 0
00803     std::cout << "ob =" << std::endl;
00804     for (auto ii = 0; ii < ob_ld; ++ii) {
00805       std::cout << std::setw(12) << ob[ii] << std::endl;
00806     }
00807     std::cout << std::endl;
00808     #endif
00809
00811
00812     // This implies a DAXPY operation. However, we must construct the arguments
00813     // for this operation.
00814
00816     // Save them into the ob_bottom array:
00817
00818     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00819
00820     try {
00821       ob_bottom = new mtk::Real[dim_null_];
00822     } catch (std::bad_alloc &memory_allocation_exception) {
00823       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00824         std::endl;
00825       std::cerr << memory_allocation_exception.what() << std::endl;
00826     }
00827     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00828
00829     for (auto ii = 0; ii < dim_null_; ++ii) {
00830       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00831     }
00832
00833     #if MTK_DEBUG_LEVEL > 0
00834     std::cout << "ob_bottom =" << std::endl;
00835     for (auto ii = 0; ii < dim_null_; ++ii) {
00836       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00837     }
00838     std::cout << std::endl;
00839     #endif
00840
00842
00843     // We must computed an scaled ob, sob, using the scaled null-space in
00844     // rat_basis_null_space_.
00845     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00846     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00847     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00848
00849     #if MTK_DEBUG_LEVEL > 0
00850     std::cout << "Rational basis for the null-space:" << std::endl;
00851     std::cout << rat_basis_null_space_ << std::endl;
00852     #endif
00853
00854     mtk::Real alpha{-mtk::kOne};
00855     mtk::Real beta{mtk::kOne};
00856
00857     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00858                                   ob_bottom, beta, ob);
00859
00860     #if MTK_DEBUG_LEVEL > 0
00861     std::cout << "scaled ob:" << std::endl;
00862     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00863       std::cout << std::setw(12) << ob[ii] << std::endl;
00864     }
```

```
00865     std::cout << std::endl;
00866     #endif
00867
00868     // We save the recently scaled solution, into an array containing these.
00869     // We can NOT start building the pi matrix, simply because I want that part
00870     // to be separated since its construction depends on the algorithm we want
00871     // to implement.
00872
00873     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00874       prem_apps_[ii*dim_null_ + ll] = ob[ii];
00875     }
00876
00877     // After the first iteration, simply shift the entries of the last
00878     // generator vector used:
00879     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00880       gg[ii]--;
00881     }
00882
00883     // Garbage collection for this loop:
00884     delete[] ob;
00885     ob = nullptr;
00886
00887     delete[] ob_bottom;
00888     ob_bottom = nullptr;
00889   } // End of: for (ll = 0; ll < dim_null; ll++);
00890
00891   #if MTK_DEBUG_LEVEL > 0
00892   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00893   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00894     for (auto jj = 0; jj < dim_null_; ++jj) {
00895       std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00896     }
00897     std::cout << std::endl;
00898   }
00899   std::cout << std::endl;
00900   #endif
00901
00902   delete[] gg;
00903   gg = nullptr;
00904
00905   return true;
00906 }
00907
00908 bool mtk::Div1D::ComputeWeights(void) {
00909
00910   // Matrix to copmpute the weights as in the CRSA.
00911   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00912
00914
00915   // Assemble the pi matrix using:
00916   // 1. The collection of scaled preliminary approximations.
00917   // 2. The collection of coefficients approximating at the interior.
00918   // 3. The scaled basis for the null-space.
00919
00920   // 1.1. Process array of scaled preliminary approximations.
00921
00922   // These are queued in scaled_solutions. Each one of these, will be a column
00923   // of the pi matrix:
00924   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00925     for (auto jj = 0; jj < dim_null_; ++jj) {
00926       pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00927         prem_apps_[ii*dim_null_ + jj];
00928     }
00929   }
00930
00931   // 1.2. Add columns from known stencil approximating at the interior.
00932
00933   // However, these must be padded by zeros, according to their position in the
00934   // final pi matrix:
00935   auto mm = 0;
00936   for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00937     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00938       pi.data()[(ii + mm)*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00939         coeffs_interior_[ii];
00940     }
00941     ++mm;
00942   }
00943
00944   rat_basis_null_space_.OrderColMajor();
00945
00946   #if MTK_DEBUG_LEVEL > 0
```

```
00947   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00948   std::cout << rat_basis_null_space_ << std::endl;
00949   #endif
00950
00951   // 1.3. Add final set of columns: rational basis for null-space.
00952   for (auto jj = dim_null_ + (order_accuracy_/2 + 1); jj < num_bndy_coeffs_ - 1; ++jj) {
00953     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00954       auto og =
00955         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00956       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00957       pi.data()[de] = rat_basis_null_space_.data()[og];
00958     }
00959   }
00960
00961   #if MTK_DEBUG_LEVEL >0
00962   std::cout << "coeffs_interior_ =" << std::endl;
00963   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00964     std::cout << std::setw(12) << coeffs_interior_[ii];
00965   }
00966   std::cout << std::endl << std::endl;
00967   #endif
00968
00969   #if MTK_DEBUG_LEVEL >0
00970   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00971   std::cout << pi << std::endl;
00972   #endif
00973
00975
00976   // This imposes the mimetic condition.
00977
00978   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
00979
00980   try {
00981     hh = new mtk::Real[num_bndy_coeffs_];
00982   } catch (std::bad_alloc &memory_allocation_exception) {
00983     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00984       std::endl;
00985     std::cerr << memory_allocation_exception.what() << std::endl;
00986   }
00987   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00988
00989   hh[0] = -mtk::kOne;
00990   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00991     auto aux_xx = mtk::kZero;
00992     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00993       aux_xx += coeffs_interior_[jj];
00994     }
00995     hh[ii] = -mtk::kOne*aux_xx;
00996   }
00997
00999
01000   // That is, we construct a system, to solve for the weights.
01001
01002   // Once again we face the challenge of solving with LAPACK. However, for the
01003   // CRSA, this matrix PI is over-determined, since it has more rows than
01004   // unknowns. However, according to the theory, the solution to this system is
01005   // unique. We will use dgels_.
01006
01007   try {
01008     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01009   } catch (std::bad_alloc &memory_allocation_exception) {
01010     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01011       std::endl;
01012     std::cerr << memory_allocation_exception.what() << std::endl;
01013   }
01014   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01015
01016   int weights_ld{pi.num_cols() + 1};
01017
01018   // Preserve hh.
01019   std::copy(hh, hh + weights_ld, weights_cbs_);
01020
01021   pi.Transpose();
01022
01023   int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
      pi, weights_cbs_, weights_ld)};
01024
01025   #if MTK_DEBUG_LEVEL > 0
01026   if (!info) {
01027     std::cout << "System successfully solved!" << std::endl << std::endl;
01028   } else {
```

```
01029     std::cerr << "Error solving system! info = " << info << std::endl;
01030   }
01031   #endif
01032
01033   #if MTK_DEBUG_LEVEL > 0
01034   std::cout << "hh =" << std::endl;
01035   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01036     std::cout << std::setw(11) << hh[ii] << std::endl;
01037   }
01038   std::cout << std::endl;
01039   #endif
01040
01041   // Preserve the original weights for research.
01042
01043   try {
01044     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01045   } catch (std::bad_alloc &memory_allocation_exception) {
01046     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01047       std::endl;
01048     std::cerr << memory_allocation_exception.what() << std::endl;
01049   }
01050   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01051
01052   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01053
01054   #if MTK_DEBUG_LEVEL > 0
01055   std::cout << "weights_CRSA + lambda =" << std::endl;
01056   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01057     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01058   }
01059   std::cout << std::endl;
01060   #endif
01061
01063
01064   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01065
01066     int minrow_{std::numeric_limits<int>::infinity()};
01067
01068     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01069     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01070
01072
01073     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01074
01075     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01076       for (auto jj = 0; jj < dim_null_; ++jj) {
01077         phi.data()[ii*(order_accuracy_) + jj] = prem_apps_[ii*dim_null_ + jj];
01078       }
01079     }
01080
01081     int aux{};  // Auxiliary variable.
01082     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01083       for (auto ii = 0; ii < order_accuracy_; ++ii) {
01084         phi.data()[(ii + aux)*order_accuracy_ + jj] = coeffs_interior_[ii];
01085       }
01086       ++aux;
01087     }
01088
01089     for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01090       for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01091         phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01092       }
01093     }
01094
01095     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01096       for (auto ii = 0; ii < dim_null_; ++ii) {
01097         phi.data()[(ii + order_accuracy_ - dim_null_ + jj*order_accuracy_)] =
01098           -prem_apps_[(dim_null_ - ii - 1 + jj*dim_null_)];
01099       }
01100     }
01101
01102     for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
01103       for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01104         auto swap = phi.data()[ii*order_accuracy_+jj];
01105         phi.data()[ii*order_accuracy_ + jj] =
01106           phi.data()[(order_accuracy_-ii)*order_accuracy_+jj];
01107         phi.data()[(order_accuracy_-ii)*order_accuracy_+jj] = swap;
01108       }
01109     }
01110
```

```
01111     #if MTK_DEBUG_LEVEL > 0
01112     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01113     std::cout << phi << std::endl;
01114     #endif
01115
01117
01118     mtk::Real *lamed{};  // Used to build big lambda.
01119
01120     try {
01121       lamed = new mtk::Real[dim_null_];
01122     } catch (std::bad_alloc &memory_allocation_exception) {
01123       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01124         std::endl;
01125       std::cerr << memory_allocation_exception.what() << std::endl;
01126     }
01127     memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01128
01129     for (auto ii = 0; ii < dim_null_; ++ii) {
01130       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01131     }
01132
01133     #if MTK_DEBUG_LEVEL > 0
01134     std::cout << "lamed =" << std::endl;
01135     for (auto ii = 0; ii < dim_null_; ++ii) {
01136       std::cout << std::setw(12) << lamed[ii] << std::endl;
01137     }
01138     std::cout << std::endl;
01139     #endif
01140
01141     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01142       mtk::Real temp = mtk::kZero;
01143       for(auto jj = 0; jj < dim_null_; ++jj) {
01144         temp = temp +
01145           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01146       }
01147       hh[ii] = hh[ii] - temp;
01148     }
01149
01150     #if MTK_DEBUG_LEVEL > 0
01151     std::cout << "big_lambda =" << std::endl;
01152     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01153       std::cout << std::setw(12) << hh[ii] << std::endl;
01154     }
01155     std::cout << std::endl;
01156     #endif
01157
01158     int copy_result{};
01159
01160     mtk::Real normerr_; // Norm of the error for the solution on each row.
01161
01163
01164     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01165       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      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       mtk::Real aux{normerr_/norm_};
01175
01176       #if MTK_DEBUG_LEVEL>0
01177       std::cout << "Relative norm: " << aux << " " << std::endl;
01178       std::cout << std::endl;
01179       #endif
01180
01181       if (aux < minnorm_) {
01182         minnorm_ = aux;
01183         minrow_= row_;
01184       }
01185     }
01186
01187     #if MTK_DEBUG_LEVEL > 0
01188     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01189       std::endl;
01190     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01191       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01192     }
```

```
01193     std::cout << std::endl;
01194     #endif
01195
01197
01198     // After we know which row yields the smallest relative norm that row is
01199     // chosen to be the objective function and the result of the optimizer is
01200     // chosen to be the new weights_.
01201
01202     #if MTK_DEBUG_LEVEL > 0
01203     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01204       minrow_ + 1 << std::endl;
01205     std::cout << std::endl;
01206     #endif
01207
01208     copy_result = 1;
01209     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01210                                                         order_accuracy_ + 1,
01211                                                         order_accuracy_,
01212                                                         order_accuracy_,
01213                                                         hh,
01214                                                         weights_cbs_,
01215                                                         minrow_,
01216                                                         mimetic_threshold_,
01217                                                         copy_result);
01218     mtk::Real aux_{normerr_/norm_};
01219     #if MTK_DEBUG_LEVEL > 0
01220     std::cout << "Relative norm: " << aux_ << std::endl;
01221     std::cout << std::endl;
01222     #endif
01223
01224     delete [] lamed;
01225     lamed = nullptr;
01226   }
01227
01228   delete [] hh;
01229   hh = nullptr;
01230
01231   return true;
01232 }
01233
01234 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01235
01236   #if MTK_DEBUG_LEVEL > 0
01237   std::cout << "weights_CBSA + lambda =" << std::endl;
01238   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01239     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01240   }
01241   std::cout << std::endl;
01242   #endif
01243
01245
01246   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01247
01248   try {
01249     lambda = new mtk::Real[dim_null_];
01250   } catch (std::bad_alloc &memory_allocation_exception) {
01251     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01252       std::endl;
01253     std::cerr << memory_allocation_exception.what() << std::endl;
01254   }
01255   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01256
01257   for (auto ii = 0; ii < dim_null_; ++ii) {
01258     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01259   }
01260
01261   #if MTK_DEBUG_LEVEL > 0
01262   std::cout << "lambda =" << std::endl;
01263   for (auto ii = 0; ii < dim_null_; ++ii) {
01264     std::cout << std::setw(12) << lambda[ii] << std::endl;
01265   }
01266   std::cout << std::endl;
01267   #endif
01268
01270
01271   mtk::Real *alpha{}; // Collection of alpha values.
01272
01273   try {
01274     alpha = new mtk::Real[dim_null_];
01275   } catch (std::bad_alloc &memory_allocation_exception) {
```

```
01276     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01277       std::endl;
01278     std::cerr << memory_allocation_exception.what() << std::endl;
01279   }
01280   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01281
01282   for (auto ii = 0; ii < dim_null_; ++ii) {
01283     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01284   }
01285
01286   #if MTK_DEBUG_LEVEL > 0
01287   std::cout << "alpha =" << std::endl;
01288   for (auto ii = 0; ii < dim_null_; ++ii) {
01289     std::cout << std::setw(12) << alpha[ii] << std::endl;
01290   }
01291   std::cout << std::endl;
01292   #endif
01293
01295
01296   try {
01297     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01298   } catch (std::bad_alloc &memory_allocation_exception) {
01299     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01300       std::endl;
01301     std::cerr << memory_allocation_exception.what() << std::endl;
01302   }
01303   memset(mim_bndy_, mtk::kZero, sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01304
01305   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01306     for (auto jj = 0; jj < dim_null_; ++jj) {
01307       mim_bndy_[ii*dim_null_ + jj] =
01308         prem_apps_[ii*dim_null_ + jj] +
01309         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01310     }
01311   }
01312
01313   #if MTK_DEBUG_LEVEL >0
01314   std::cout << "Collection of mimetic approximations:" << std::endl;
01315   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01316     for (auto jj = 0; jj < dim_null_; ++jj) {
01317       std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01318     }
01319     std::cout << std::endl;
01320   }
01321   std::cout << std::endl;
01322   #endif
01323
01324   delete[] lambda;
01325   lambda = nullptr;
01326
01327   delete[] alpha;
01328   alpha = nullptr;
01329
01330   return true;
01331 }
01332
01333 bool mtk::Div1D::AssembleOperator(void) {
01334
01335   // The output array will have this form:
01336   // 1. The first entry of the array will contain the used order order_accuracy_.
01337   // 2. The second entry of the array will contain the collection of
01338   // approximating coefficients for the interior of the grid.
01339   // 3. IF order_accuracy_ > 2, then the third entry will contain a collection of weights.
01340   // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the collections of
01341   // approximating coefficients for the west boundary of the grid.
01342
01343   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01344     divergence_length_ =
01345       1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
01346   } else {
01347     divergence_length_ = 1 + order_accuracy_;
01348   }
01349
01350   #if MTK_DEBUG_LEVEL > 0
01351   std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01352   #endif
01353
01354   try {
01355     divergence_ = new double[divergence_length_];
01356   } catch (std::bad_alloc &memory_allocation_exception) {
01357     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
```

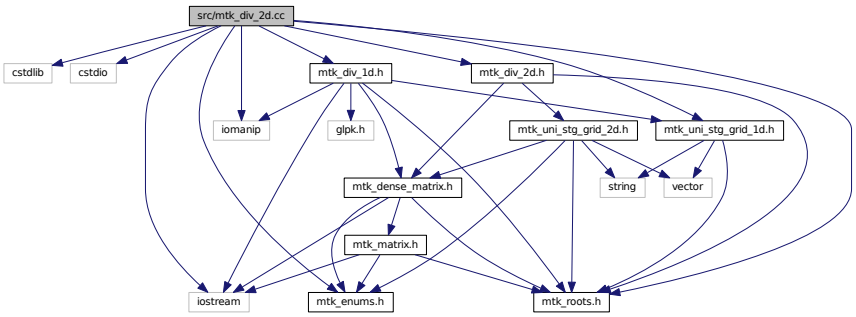
```
01358       std::endl;
01359     std::cerr << memory_allocation_exception.what() << std::endl;
01360   }
01361   memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01362
01364
01365   divergence_[0] = order_accuracy_;
01366
01368
01369   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01370   divergence_[ii + 1] = coeffs_interior_[ii];
01371   }
01372
01374
01375   if (order_accuracy_ > 2) {
01376     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01377       divergence_[(1 + order_accuracy_) + ii] = weights_cbs_[ii];
01378     }
01379   }
01380
01383
01384   if (order_accuracy_ > 2) {
01385     auto offset = (2*order_accuracy_ + 1);
01386     int mm{};
01387     for (auto ii = 0; ii < dim_null_; ++ii) {
01388       for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01389         divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01390         ++mm;
01391       }
01392     }
01393   }
01394
01395   #if MTK_DEBUG_LEVEL > 0
01396   std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01397   std::cout << std::endl;
01398   #endif
01399
01400   return true;
01401 }
```

## 17.63 src/mtk_div_2d.cc File Reference

Implements the class Div2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_div_1d.h"
#include "mtk_div_2d.h"
```

Include dependency graph for mtk_div_2d.cc:




### 17.63.1 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
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 <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_1d.h"
00066 #include "mtk_div_1d.h"
00067 #include "mtk_div_2d.h"
00068
00069 mtk::Div2D::Div2D():
00070   order_accuracy_(),
00071   mimetic_threshold_() {}
00072
00073 mtk::Div2D::Div2D(const Div2D &div):
00074   order_accuracy_(div.order_accuracy_),
00075   mimetic_threshold_(div.mimetic_threshold_) {}
00076
00077 mtk::Div2D::~Div2D() {}
00078
00079 bool mtk::Div2D::ConstructDiv2D(const
      mtk::UniStgGrid2D &grid,
00080                                 int order_accuracy,
00081                                 mtk::Real mimetic_threshold) {
00082
00083   int num_cells_x = grid.num_cells_x();
00084   int num_cells_y = grid.num_cells_y();
00085
00086   int mx = num_cells_x + 2;  // Gx vertical dimension
00087   int nx = num_cells_x + 1;  // Gx horizontal dimension
00088   int my = num_cells_y + 2;  // Gy vertical dimension
00089   int ny = num_cells_y + 1;  // Gy 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 << "Gx :" << mx << "by " << nx << std::endl;
00122   std::cout << "Transpose iy : " << num_cells_y<< " by " << ny  << std::endl;
00123   std::cout << "Gy :" << my << "by " << ny << std::endl;
```

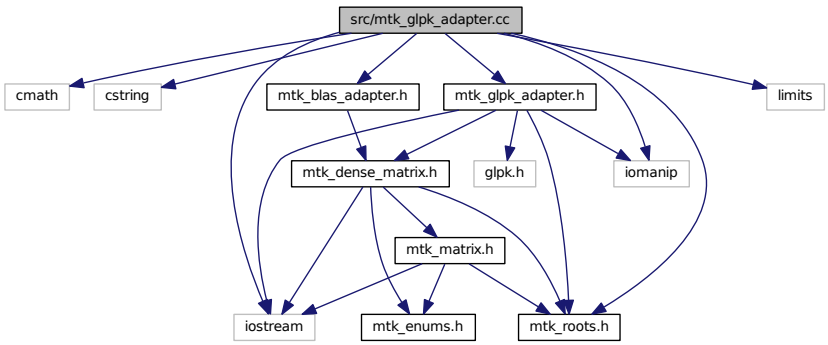
```
00124   std::cout << "Transpose ix : " << num_cells_x<< " by " << nx  << std::endl;
00125   std::cout << "Kronecker dimensions Grad 2D" <<
00126   mx*num_cells_y + my*num_cells_x << " by " <<  nx*ny <<std::endl;
00127   #endif
00128
00129   mtk::DenseMatrix d2d(mx*my,nx*num_cells_y + ny*num_cells_x);
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() {
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 /*
00020 Copyright (C) 2015, Computational Science Research Center, San Diego State
00021 University. All rights reserved.
00022
00023 Redistribution and use in source and binary forms, with or without modification,
00024 are permitted provided that the following conditions are met:
00025
00026 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00034
00035 3. Redistributions in binary form must reproduce the above copyright notice,
00036 this list of conditions and the following disclaimer in the documentation and/or
00037 other materials provided with the distribution.
00038
00039 4. Usage of the binary form on proprietary applications shall require explicit
00040 prior written permission from the the copyright holders, and due credit should
00041 be given to the copyright holders.
00042
00043 5. Neither the name of the copyright holder nor the names of its contributors
00044 may be used to endorse or promote products derived from this software without
00045 specific prior written permission.
00046
00047 The copyright holders provide no reassurances that the source code provided does
00048 not infringe any patent, copyright, or any other intellectual property rights of
00049 third parties. The copyright holders disclaim any liability to any recipient for
00050 claims brought against recipient by any third party for infringement of that
00051 parties intellectual property rights.
00052
00053 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00054 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00055 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00056 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00057 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00058 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00059 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #include <cmath>
00066 #include <cstring>
00067
00068 #include <iostream>
00069 #include <iomanip>
00070 #include <limits>
00071
00072 #include "mtk_roots.h"
```

```
00073 #include "mtk_blas_adapter.h"
00074 #include "mtk_glpk_adapter.h"
00075
00076 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
      mtk::Real *A,
00077                                                   int nrows,
00078                                                   int ncols,
00079                                                   int kk,
00080                                                   mtk::Real *hh,
00081                                                   mtk::Real *qq,
00082                                                   int robjective,
00083                                                   mtk::Real mimetic_threshold,
00084                                                   int copy) {
00085
00086   #if MTK_DEBUG_LEVEL > 0
00087   char mps_file_name[18]; // File name for the MPS files.
00088   #endif
00089   char rname[5];          // Row name.
00090   char cname[5];          // Column name.
00091
00092   glp_prob *lp; // Linear programming problem.
00093
00094   int *ia;  // Array for the problem.
00095   int *ja;  // Array for the problem.
00096
00097   int problem_size; // Size of the problem.
00098   int lp_nrows;     // Number of rows.
00099   int lp_ncols;     // Number of columns.
00100   int matsize;      // Size of the matrix.
00101   int glp_index{1}; // Index of the objective function.
00102   int ii;           // Iterator.
00103   int jj;           // Iterator.
00104
00105   mtk::Real *ar;            // Array for the problem.
00106   mtk::Real *objective;     // Array containing the objective function.
00107   mtk::Real *rhs;           // Array containing the rhs.
00108   mtk::Real *err;           // Array of errors.
00109
00110   mtk::Real xl;             // Norm-2 of the error.
00111
00112   #if MTK_DEBUG_LEVEL > 0
00113   mtk::Real obj_value;      // Value of the objective function.
00114   #endif
00115
00116   lp_nrows = kk;
00117   lp_ncols = kk;
00118
00119   matsize = lp_nrows*lp_ncols;
00120
00122
00124   problem_size = lp_nrows*lp_ncols + 1;
00125
00126   try {
00127     ia = new int[problem_size];
00128   } catch (std::bad_alloc &memory_allocation_exception) {
00129     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00130       std::endl;
00131     std::cerr << memory_allocation_exception.what() << std::endl;
00132   }
00133   memset(ia, 0, sizeof(ia[0])*problem_size);
00134
00135   try {
00136     ja = new int[problem_size];
00137   } catch (std::bad_alloc &memory_allocation_exception) {
00138     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00139       std::endl;
00140     std::cerr << memory_allocation_exception.what() << std::endl;
00141   }
00142   memset(ja, 0, sizeof(ja[0])*problem_size);
00143
00144   try {
00145     ar = new mtk::Real[problem_size];
00146   } catch (std::bad_alloc &memory_allocation_exception) {
00147     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00148       std::endl;
00149     std::cerr << memory_allocation_exception.what() << std::endl;
00150   }
00151   memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00152
00153   try {
00154     objective = new mtk::Real[lp_ncols + 1];
```

```
00155   } catch (std::bad_alloc &memory_allocation_exception) {
00156     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00157       std::endl;
00158     std::cerr << memory_allocation_exception.what() << std::endl;
00159   }
00160   memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00161
00162   try {
00163     rhs = new mtk::Real[lp_nrows + 1];
00164   } catch (std::bad_alloc &memory_allocation_exception) {
00165     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00166       std::endl;
00167     std::cerr << memory_allocation_exception.what() << std::endl;
00168   }
00169   memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00170
00171   try {
00172     err = new mtk::Real[lp_nrows];
00173   } catch (std::bad_alloc &memory_allocation_exception) {
00174     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00175       std::endl;
00176     std::cerr << memory_allocation_exception.what() << std::endl;
00177   }
00178   memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00179
00180   #if MTK_DEBUG_LEVEL > 0
00181   std::cout << "Problem size: " << problem_size << std::endl;
00182   std::cout << "lp_nrows = " << lp_nrows << std::endl;
00183   std::cout << "lp_ncols = " << lp_ncols << std::endl;
00184   std::cout << std::endl;
00185   #endif
00186
00187   lp = glp_create_prob();
00188
00189   glp_set_prob_name (lp, "mtk::GLPKAdapter::Simplex");
00190
00191   glp_set_obj_dir (lp, GLP_MIN);
00192
00194
00195   glp_add_rows(lp, lp_nrows);
00196
00197   for (ii = 1; ii <= lp_nrows; ++ii) {
00198     sprintf(rname, "R%02d",ii);
00199     glp_set_row_name(lp, ii, rname);
00200   }
00201
00202   glp_add_cols(lp, lp_ncols);
00203
00204   for (ii = 1; ii <= lp_ncols; ++ii) {
00205     sprintf(cname, "Q%02d",ii);
00206     glp_set_col_name (lp, ii, cname);
00207   }
00208
00210
00211   #if MTK_DEBUG_LEVEL>0
00212   std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00213   #endif
00214   for (jj = 0; jj < kk; ++jj) {
00215     objective[glp_index] = A[jj + robjective * ncols];
00216     glp_index++;
00217   }
00218   #if MTK_DEBUG_LEVEL >0
00219   std::cout << std::endl;
00220   #endif
00221
00223
00224   glp_index = 1;
00225   rhs[0] = mtk::kZero;
00226   for (ii = 0; ii <= lp_nrows; ++ii) {
00227     if (ii != robjective) {
00228       rhs[glp_index] = hh[ii];
00229       glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00230       glp_index++;
00231     }
00232   }
00233
00234   #if MTK_DEBUG_LEVEL > 0
00235   std::cout << "rhs =" << std::endl;
00236   for (auto ii = 0; ii < lp_nrows; ++ii) {
00237     std::cout << std::setw(15) << rhs[ii] << std::endl;
00238   }
```

```
00239   std::cout << std::endl;
00240   #endif
00241
00243
00244   for (ii = 1; ii <= lp_ncols; ++ii) {
00245     glp_set_obj_coef (lp, ii, objective[ii]);
00246   }
00247
00249
00250   for (ii = 1; ii <= lp_ncols; ++ii) {
00251     glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00252   }
00253
00255
00256   glp_index = 1;
00257   for (ii = 0; ii <= kk; ++ii) {
00258     for (jj = 0; jj < kk; ++jj) {
00259       if (ii != robjective) {
00260         ar[glp_index] = A[jj + ii * ncols];
00261         glp_index++;
00262       }
00263     }
00264   }
00265
00266   glp_index = 0;
00267
00268   for (ii = 1; ii < problem_size; ++ii) {
00269     if (((ii - 1) % lp_ncols) == 0) {
00270       glp_index++;
00271     }
00272     ia[ii] = glp_index;
00273     ja[ii] = (ii - 1) % lp_ncols + 1;
00274   }
00275
00276   glp_load_matrix (lp, matsize, ia, ja, ar);
00277
00278   #if MTK_DEBUG_LEVEL > 0
00279   sprintf(mps_file_name, "LP_MPS_row_%02d.mps", robjective);
00280   glp_write_mps(lp, GLP_MPS_FILE, nullptr, mps_file_name);
00281   #endif
00282
00284
00285   glp_simplex (lp, nullptr);
00286
00287   // Check status of the solution.
00288
00289   if (glp_get_status(lp) == GLP_OPT) {
00290
00291     for(ii = 1; ii <= lp_ncols; ++ii) {
00292       err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp,ii);
00293     }
00294
00295     #if MTK_DEBUG_LEVEL > 0
00296     obj_value = glp_get_obj_val (lp);
00297     std::cout << std::setw(12) << "CBS" << std::setw(12) << "CRS" << std::endl;
00298     for (ii = 0; ii < lp_ncols; ++ii) {
00299       std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00300         glp_get_col_prim(lp,ii + 1) << std::setw(12) << qq[ii] << std::endl;
00301     }
00302     std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00303       obj_value << std::endl;
00304     #endif
00305
00306     if (copy) {
00307       for(ii = 0; ii < lp_ncols; ++ii) {
00308         qq[ii] = glp_get_col_prim(lp,ii + 1);
00309       }
00310       // Preserve the bottom values of qq.
00311     }
00312
00313     x1 = mtk::BLASAdapter::RealNRM2(err,lp_ncols);
00314
00315   } else {
00316     x1 = std::numeric_limits<mtk::Real>::infinity();
00317   }
00318
00319   glp_delete_prob (lp);
00320   glp_free_env ();
00321
00322   delete [] ia;
00323   delete [] ja;
```

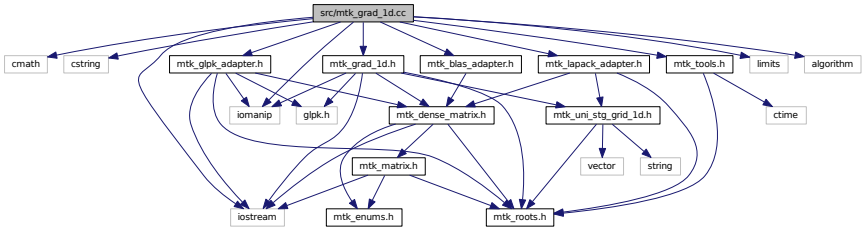
```
00324   delete [] ar;
00325   delete [] objective;
00326   delete [] rhs;
00327   delete [] err;
00328
00329   return x1;
00330 }
```

## 17.67 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**

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

**Todo** Overload ostream operator as in mtk::Lap1D.

**Todo** Implement creation of ■ w. mtk::BLASAdapter.

Definition in file mtk_grad_1d.cc.

## 17.68 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
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
00039 5. Neither the name of the copyright holder nor the names of its contributors
00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
00042
00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00050 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
```

```
00075 #include "mtk_grad_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Grad1D &in) {
00080
00082
00083   stream << "gradient_[0] = " << std::setw(9) << in.gradient_[0] << std::endl;
00084
00086
00087   stream << "gradient_[1:" << in.order_accuracy_ << "] = ";
00088   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00089     stream << std::setw(9) << in.gradient_[ii] << " ";
00090   }
00091   stream << std::endl;
00092
00094
00095   stream << "gradient_[" << in.order_accuracy_ + 1 << ":" <<
00096     2*in.order_accuracy_ << "] = ";
00097   for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00098     stream << std::setw(9) << in.gradient_[ii] << " ";
00099   }
00100   stream << std::endl;
00101
00103
00104   int offset{2*in.order_accuracy_ + 1};
00105   int mm {};
00106
00107   stream << "gradient_[" << offset + mm << ":" <<
00108     offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00109
00110   if (in.order_accuracy_ > mtk::kDefaultOrderAccuracy) {
00111     for (auto ii = 0; ii < in.num_bndy_approxs_ ; ++ii) {
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; jj++) {
00113         auto value = in.gradient_[offset + (mm)];
00114         stream << std::setw(9) << value << " ";
00115         mm++;
00116       }
00117     }
00118   } else {
00119     stream << std::setw(9) << in.gradient_[offset + 0] << ' ';
00120     stream << std::setw(9) << in.gradient_[offset + 1] << ' ';
00121     stream << std::setw(9) << in.gradient_[offset + 2] << ' ';
00122   }
00123   stream << std::endl;
00124
00125   return stream;
00126 }
00127 }
00128
00129 mtk::Grad1D::Grad1D():
00130   order_accuracy_(mtk::kDefaultOrderAccuracy),
00131   dim_null_(),
00132   num_bndy_approxs_(),
00133   num_bndy_coeffs_(),
00134   gradient_length_(),
00135   minrow_(),
00136   row_(),
00137   coeffs_interior_(),
00138   prem_apps_(),
00139   weights_crs_(),
00140   weights_cbs_(),
00141   mim_bndy_(),
00142   gradient_(),
00143   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00144
00145 mtk::Grad1D::Grad1D(const Grad1D &grad):
00146   order_accuracy_(grad.order_accuracy_),
00147   dim_null_(grad.dim_null_),
00148   num_bndy_approxs_(grad.num_bndy_approxs_),
00149   num_bndy_coeffs_(grad.num_bndy_coeffs_),
00150   gradient_length_(grad.gradient_length_),
00151   minrow_(grad.minrow_),
00152   row_(grad.row_),
00153   coeffs_interior_(grad.coeffs_interior_),
00154   prem_apps_(grad.prem_apps_),
00155   weights_crs_(grad.weights_crs_),
00156   weights_cbs_(grad.weights_cbs_),
00157   mim_bndy_(grad.mim_bndy_),
00158   gradient_(grad.gradient_),
```

```
00159   mimetic_threshold_(grad.mimetic_threshold_) {}
00160
00161 mtk::Grad1D::~Grad1D() {
00162
00163   delete[] coeffs_interior_;
00164   coeffs_interior_ = nullptr;
00165
00166   delete[] prem_apps_;
00167   prem_apps_ = nullptr;
00168
00169   delete[] weights_crs_;
00170   weights_crs_ = nullptr;
00171
00172   delete[] weights_cbs_;
00173   weights_cbs_ = nullptr;
00174
00175   delete[] mim_bndy_;
00176   mim_bndy_ = nullptr;
00177
00178   delete[] gradient_;
00179   gradient_ = nullptr;
00180 }
00181
00182 bool mtk::Grad1D::ConstructGrad1D(int order_accuracy,
      Real mimetic_threshold) {
00183
00184   #if MTK_DEBUG_LEVEL > 0
00185   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00186   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00187   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00188                       __FILE__, __LINE__, __func__);
00189
00190   if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00191     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00192   }
00193
00194   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00195   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00196   #endif
00197
00198   order_accuracy_ = order_accuracy;
00199   mimetic_threshold_ = mimetic_threshold;
00200
00202
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
00327   return num_bndy_coeffs_;
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(
    mtk::Real west,
00361                                                   mtk::Real east,
00362                                                   int num_cells_x) {
00363
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
00385
00386   auto ee_index = 0;
00387   for (auto ii = 0; ii < num_extra_rows; ii++) {
00388     auto cc = 0;
00389     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00390       if(cc >= elements_per_row) {
00391         out.SetValue(ii, jj, mtk::kZero);
00392       } else {
00393         out.SetValue(ii,jj,
00394                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00395         cc++;
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
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(const
      UniStgGrid1D &grid) {
00429
00430   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00431
00432   #if MTK_DEBUG_LEVEL > 0
00433   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00434   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00435   #endif
00436
00437   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00438
00439   int gg_num_rows = nn + 1;
00440   int gg_num_cols = nn + 2;
00441   int elements_per_row = num_bndy_coeffs_;
00442   int num_extra_rows = order_accuracy_/2;
00443
00444   // Output matrix featuring sizes for gradient operators.
00445   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00446
00448
00449   auto ee_index = 0;
00450   for (auto ii = 0; ii < num_extra_rows; ii++) {
00451     auto cc = 0;
00452     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00453       if(cc >= elements_per_row) {
00454         out.SetValue(ii, jj, mtk::kZero);
00455       } else {
00456         out.SetValue(ii,jj,
00457                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00458         cc++;
00459       }
00460     }
00461   }
00462
00464
00465   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00466     auto jj = ii - num_extra_rows + 1;
00467     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00468       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00469     }
00470   }
00471
00473
00474   ee_index = 0;
00475   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00476     auto cc = 0;
00477     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00478       if(cc >= elements_per_row) {
00479         out.SetValue(ii,jj,mtk::kZero);
00480       } else {
00481         out.SetValue(ii,jj,
00482                      -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00483         cc++;
00484       }
00485      }
00486   }
00487
00488   return out;
00489 }
00490
00491 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix
```

```
    (int num_cells_x) {
00492
00493   int nn{num_cells_x}; // Number of cells on the grid.
00494
00495   #if MTK_DEBUG_LEVEL > 0
00496   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00497   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00498   #endif
00499
00500   int gg_num_rows = nn + 1;
00501   int gg_num_cols = nn + 2;
00502   int elements_per_row = num_bndy_coeffs_;
00503   int num_extra_rows = order_accuracy_/2;
00504
00505   // Output matrix featuring sizes for gradient operators.
00506   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00507
00509
00510   auto ee_index = 0;
00511   for (auto ii = 0; ii < num_extra_rows; ii++) {
00512     auto cc = 0;
00513     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00514       if(cc >= elements_per_row) {
00515         out.SetValue(ii, jj, mtk::kZero);
00516       } else {
00517         out.SetValue(ii,jj,
00518                      gradient_[2*order_accuracy_ + 1 + ee_index++]);
00519         cc++;
00520       }
00521     }
00522   }
00523
00525
00526   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00527     auto jj = ii - num_extra_rows + 1;
00528     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00529       out.SetValue(ii, jj, coeffs_interior_[cc]);
00530     }
00531   }
00532
00534
00535   ee_index = 0;
00536   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00537     auto cc = 0;
00538     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00539       if(cc >= elements_per_row) {
00540         out.SetValue(ii,jj,mtk::kZero);
00541       } else {
00542         out.SetValue(ii,jj,
00543                      -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00544         cc++;
00545       }
00546      }
00547   }
00548
00549   return out;
00550 }
00551
00552 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00553
00555
00556   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00557
00558   try {
00559     pp = new mtk::Real[order_accuracy_];
00560   } catch (std::bad_alloc &memory_allocation_exception) {
00561     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00562       std::endl;
00563     std::cerr << memory_allocation_exception.what() << std::endl;
00564   }
00565   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00566
00567   #ifdef MTK_PRECISION_DOUBLE
00568   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00569   #else
00570   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00571   #endif
00572
00573   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00574     pp[ii] = pp[ii - 1] + mtk::kOne;
00575   }
```

```
00576
00577   #if MTK_DEBUG_LEVEL > 0
00578   std::cout << "pp =" << std::endl;
00579   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00580     std::cout << std::setw(12) << pp[ii];
00581   }
00582   std::cout << std::endl << std::endl;
00583   #endif
00584
00586
00587   bool transpose{false};
00588
00589   mtk::DenseMatrix vander_matrix(pp,order_accuracy_,order_accuracy_,transpose);
00590
00591   #if MTK_DEBUG_LEVEL > 0
00592   std::cout << "vander_matrix = " << std::endl;
00593   std::cout << vander_matrix << std::endl << std::endl;
00594   #endif
00595
00597
00598   try {
00599     coeffs_interior_ = new mtk::Real[order_accuracy_];
00600   } catch (std::bad_alloc &memory_allocation_exception) {
00601     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00602       std::endl;
00603     std::cerr << memory_allocation_exception.what() << std::endl;
00604   }
00605   memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00606
00607   coeffs_interior_[1] = mtk::kOne;
00608
00609   #if MTK_DEBUG_LEVEL > 0
00610   std::cout << "oo =" << std::endl;
00611   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00612     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00613   }
00614   std::cout << std::endl;
00615   #endif
00616
00618
00619   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00620                                                 coeffs_interior_)};
00621
00622   #if MTK_DEBUG_LEVEL > 0
00623   if (!info) {
00624     std::cout << "System solved! Interior stencil attained!" << std::endl;
00625     std::cout << std::endl;
00626   }
00627   else {
00628     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00629     std::cerr << "Exiting..." << std::endl;
00630     return false;
00631   }
00632   #endif
00633
00634   #if MTK_DEBUG_LEVEL > 0
00635   std::cout << "coeffs_interior_ =" << std::endl;
00636   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00637     std::cout << std::setw(12) << coeffs_interior_[ii];
00638   }
00639   std::cout << std::endl << std::endl;
00640   #endif
00641
00642   delete [] pp;
00643   pp = nullptr;
00644
00645   return true;
00646 }
00647
00648 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00649
00651
00652   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00653
00654   try {
00655     gg = new mtk::Real[num_bndy_coeffs_];
00656   } catch (std::bad_alloc &memory_allocation_exception) {
00657     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00658       std::endl;
00659     std::cerr << memory_allocation_exception.what() << std::endl;
00660   }
```

```
00661   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00662
00663   #ifdef MTK_PRECISION_DOUBLE
00664   gg[1] = 1.0/2.0;
00665   #else
00666   gg[1] = 1.0f/2.0f;
00667   #endif
00668   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00669     gg[ii] = gg[ii - 1] + mtk::kOne;
00670   }
00671
00672   #if MTK_DEBUG_LEVEL > 0
00673   std::cout << "gg =" << std::endl;
00674   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00675     std::cout << std::setw(12) << gg[ii];
00676   }
00677   std::cout << std::endl << std::endl;
00678   #endif
00679
00681
00682   bool tran{true}; // Should I transpose the Vandermonde matrix.
00683
00684   mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00685
00686   #if MTK_DEBUG_LEVEL > 0
00687   std::cout << "aa_west_t =" << std::endl;
00688   std::cout << aa_west_t << std::endl;
00689   #endif
00690
00692
00693   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (aa_west_t));
00694
00695   #if MTK_DEBUG_LEVEL > 0
00696   std::cout << "qq_t = " << std::endl;
00697   std::cout << qq_t << std::endl;
00698   #endif
00699
00701
00702   int kk_num_rows{num_bndy_coeffs_};
00703   int kk_num_cols{dim_null_};
00704
00705   mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00706
00707   // In the case of the gradient, even though we must solve for a null-space
00708   // of dimension 2, we must only extract ONE basis for the kernel.
00709   // We perform this extraction here:
00710
00711   int aux_{kk_num_rows - kk_num_cols};
00712   for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00713     aux_--;
00714     for (auto jj = 0; jj < kk_num_rows; jj++) {
00715       kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00716         qq_t.data()[ii*num_bndy_coeffs_ + jj];
00717     }
00718   }
00719
00720   #if MTK_DEBUG_LEVEL > 0
00721   std::cout << "kk =" << std::endl;
00722   std::cout << kk << std::endl;
00723   std::cout << "kk.num_rows() = " << kk.num_rows() << std::endl;
00724   std::cout << "kk.num_cols() = " << kk.num_cols() << std::endl;
00725   std::cout << std::endl;
00726   #endif
00727
00729
00730   // Scale thus requesting that the last entries of the attained basis for the
00731   // null-space, adopt the pattern we require.
00732   // Essentially we will implement the following MATLAB pseudo-code:
00733   //  scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00734   //  SK = kk*scalers
00735   // where SK is the scaled null-space.
00736
00737   // In this point, we almost have all the data we need correctly allocated
00738   // in memory. We will create the matrix iden_, and elements we wish to scale in
00739   // the kk array. Using the concept of the leading dimension, we could just
00740   // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00741   // GET how does it work. So I will just create a matrix with the content of
00742   // this array that we need, solve for the scalers and then scale the
00743   // whole kk:
00744
```

```
00745   // We will then create memory for that sub-matrix of kk (subk).
00746
00747   mtk::DenseMatrix subk(dim_null_, dim_null_);
00748
00749   auto zz = 0;
00750   for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00751     for (auto jj = 0; jj < dim_null_; jj++) {
00752       subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00753     }
00754     zz++;
00755   }
00756
00757   #if MTK_DEBUG_LEVEL > 0
00758   std::cout << "subk =" << std::endl;
00759   std::cout << subk << std::endl;
00760   #endif
00761
00762   subk.Transpose();
00763
00764   #if MTK_DEBUG_LEVEL > 0
00765   std::cout << "subk_t =" << std::endl;
00766   std::cout << subk << std::endl;
00767   #endif
00768
00769   bool padded{false};
00770   tran = false;
00771
00772   mtk::DenseMatrix iden(dim_null_, padded, tran);
00773
00774   #if MTK_DEBUG_LEVEL > 0
00775   std::cout << "iden =" << std::endl;
00776   std::cout << iden << std::endl;
00777   #endif
00778
00779   // Solve the system to compute the scalers.
00780   // An example of the system to solve, for k = 8, is:
00781   //
00782   // subk*scalers = iden or
00783   //
00784   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00785   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00786   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00787   //
00788   // Notice this is a nrhs = 3 system.
00789   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00790   // will be stored in the created identity matrix.
00791   // Let us first transpose subk (because of LAPACK):
00792
00793   int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00794
00795   #if MTK_DEBUG_LEVEL > 0
00796   if (!info) {
00797     std::cout << "System successfully solved!" <<
00798       std::endl;
00799   } else {
00800     std::cerr << "Something went wrong solving system! info = " << info <<
00801       std::endl;
00802     std::cerr << "Exiting..." << std::endl;
00803     return false;
00804   }
00805   std::cout << std::endl;
00806   #endif
00807
00808   #if MTK_DEBUG_LEVEL > 0
00809   std::cout << "Computed scalers:" << std::endl;
00810   std::cout << iden << std::endl;
00811   #endif
00812
00813   // Multiply the two matrices to attain a scaled basis for null-space.
00814
00815   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00816
00817   #if MTK_DEBUG_LEVEL > 0
00818   std::cout << "Rational basis for the null-space:" << std::endl;
00819   std::cout << rat_basis_null_space_ << std::endl;
00820   #endif
00821
00822   // At this point, we have a rational basis for the null-space, with the
00823   // pattern we need! :)
00824
00825   delete [] gg;
```

```
00826   gg = nullptr;
00827
00828   return true;
00829 }
00830
00831 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00832
00834
00835   mtk::Real *gg{}; // Generator vector for the first approximation.
00836
00837   try {
00838     gg = new mtk::Real[num_bndy_coeffs_];
00839   } catch (std::bad_alloc &memory_allocation_exception) {
00840     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00841       std::endl;
00842     std::cerr << memory_allocation_exception.what() << std::endl;
00843   }
00844   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00845
00846   #ifdef MTK_PRECISION_DOUBLE
00847   gg[1] = 1.0/2.0;
00848   #else
00849   gg[1] = 1.0f/2.0f;
00850   #endif
00851   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00852     gg[ii] = gg[ii - 1] + mtk::kOne;
00853   }
00854
00855   #if MTK_DEBUG_LEVEL > 0
00856   std::cout << "gg0 =" << std::endl;
00857   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00858     std::cout << std::setw(12) << gg[ii];
00859   }
00860   std::cout << std::endl << std::endl;
00861   #endif
00862
00863   // Allocate 2D array to store the collection of preliminary approximations.
00864   try {
00865     prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00866   } catch (std::bad_alloc &memory_allocation_exception) {
00867     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00868 std::endl;
00869     std::cerr << memory_allocation_exception.what() << std::endl;
00870   }
00871   memset(prem_apps_,
00872          mtk::kZero,
00873          sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00874
00876
00877   for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00878
00879     // Re-check new generator vector for every iteration except for the first.
00880     #if MTK_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
00891
00892     bool transpose{false};
00893
00894     mtk::DenseMatrix aa(gg,
00895                         num_bndy_coeffs_, order_accuracy_ + 1,
00896                         transpose);
00897
00898     #if MTK_DEBUG_LEVEL > 0
00899     std::cout << "aa_" << ll << " =" << std::endl;
00900     std::cout << aa << std::endl;
00901     #endif
00902
00904
00905     mtk::Real *ob{};
00906
00907     auto ob_ld = num_bndy_coeffs_;
00908
00909     try {
00910       ob = new mtk::Real[ob_ld];
```

```
00911     } catch (std::bad_alloc &memory_allocation_exception) {
00912       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00913         std::endl;
00914       std::cerr << memory_allocation_exception.what() << std::endl;
00915     }
00916     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00917
00918     ob[1] = mtk::kOne;
00919
00920     #if MTK_DEBUG_LEVEL > 0
00921     std::cout << "ob = " << std::endl << std::endl;
00922     for (auto ii = 0; ii < ob_ld; ++ii) {
00923       std::cout << std::setw(12) << ob[ii] << std::endl;
00924     }
00925     std::cout << std::endl;
00926     #endif
00927
00929
00930     // However, this is an under-determined system of equations. So we can not
00931     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00932     // our LAPACKAdapter class.
00933
00934     int info_{
00935       mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
      , ob_ld)};
00936
00937     #if MTK_DEBUG_LEVEL > 0
00938     if (!info_) {
00939       std::cout << "System successfully solved!" << std::endl << std::endl;
00940     } else {
00941       std::cerr << "Error solving system! info = " << info_ << std::endl;
00942     }
00943     #endif
00944
00945     #if MTK_DEBUG_LEVEL > 0
00946     std::cout << "ob =" << std::endl;
00947     for (auto ii = 0; ii < ob_ld; ++ii) {
00948       std::cout << std::setw(12) << ob[ii] << std::endl;
00949     }
00950     std::cout << std::endl;
00951     #endif
00952
00954
00955     // This implies a DAXPY operation. However, we must construct the arguments
00956     // for this operation.
00957
00959     // Save them into the ob_bottom array:
00960
00961     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00962
00963     try {
00964       ob_bottom = new mtk::Real[dim_null_];
00965     } catch (std::bad_alloc &memory_allocation_exception) {
00966       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00967         std::endl;
00968       std::cerr << memory_allocation_exception.what() << std::endl;
00969     }
00970     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00971
00972     for (auto ii = 0; ii < dim_null_; ++ii) {
00973       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00974     }
00975
00976     #if MTK_DEBUG_LEVEL > 0
00977     std::cout << "ob_bottom =" << std::endl;
00978     for (auto ii = 0; ii < dim_null_; ++ii) {
00979       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00980     }
00981     std::cout << std::endl;
00982     #endif
00983
00985
00986     // We must computed an scaled ob, sob, using the scaled null-space in
00987     // rat_basis_null_space_.
00988     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00989     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00990     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00991
00992     #if MTK_DEBUG_LEVEL > 0
00993     std::cout << "Rational basis for the null-space:" << std::endl;
00994     std::cout << rat_basis_null_space_ << std::endl;
```

```
00995     #endif
00996
00997     mtk::Real alpha{-mtk::kOne};
00998     mtk::Real beta{mtk::kOne};
00999
01000     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
01001                                   ob_bottom, beta, ob);
01002
01003     #if MTK_DEBUG_LEVEL > 0
01004     std::cout << "scaled ob:" << std::endl;
01005     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01006       std::cout << std::setw(12) << ob[ii] << std::endl;
01007     }
01008     std::cout << std::endl;
01009     #endif
01010
01011     // We save the recently scaled solution, into an array containing these.
01012     // We can NOT start building the pi matrix, simply because I want that part
01013     // to be separated since its construction depends on the algorithm we want
01014     // to implement.
01015
01016     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01017       prem_apps_[ii*num_bndy_approxs_ + ll] = ob[ii];
01018     }
01019
01020     // After the first iteration, simply shift the entries of the last
01021     // generator vector used:
01022     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01023       gg[ii]--;
01024     }
01025
01026     // Garbage collection for this loop:
01027     delete[] ob;
01028     ob = nullptr;
01029
01030     delete[] ob_bottom;
01031     ob_bottom = nullptr;
01032   } // End of: for (ll = 0; ll < dim_null; ll++);
01033
01034   #if MTK_DEBUG_LEVEL > 0
01035   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
01036   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01037     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01038       std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
01039     }
01040     std::cout << std::endl;
01041   }
01042   std::cout << std::endl;
01043   #endif
01044
01045   delete[] gg;
01046   gg = nullptr;
01047
01048   return true;
01049 }
01050
01051 bool mtk::Grad1D::ComputeWeights() {
01052
01053   // Matrix to copmpute the weights as in the CRSA.
01054   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01055
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   std::cout << std::endl << std::endl;
01113   #endif
01114
01115   #if MTK_DEBUG_LEVEL >0
01116   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01117   std::cout << pi << std::endl;
01118   #endif
01119
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   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01134
01135   hh[0] = -mtk::kOne;
01136   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01137     auto aux_xx = mtk::kZero;
01138     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01139       aux_xx += coeffs_interior_[jj];
01140     }
01141     hh[ii] = -mtk::kOne*aux_xx;
01142   }
01143
01145
01146   // That is, we construct a system, to solve for the weights.
01147
01148   // Once again we face the challenge of solving with LAPACK. However, for the
01149   // CRSA, this matrix PI is over-determined, since it has more rows than
01150   // unknowns. However, according to the theory, the solution to this system is
01151   // unique. We will use dgels_.
01152
01153   try {
01154     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01155   } catch (std::bad_alloc &memory_allocation_exception) {
01156     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01157       std::endl;
01158     std::cerr << memory_allocation_exception.what() << std::endl;
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_];
01194   } catch (std::bad_alloc &memory_allocation_exception) {
01195     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01196       std::endl;
01197     std::cerr << memory_allocation_exception.what() << std::endl;
01198   }
01199   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01200
01201   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01202
01203   #if MTK_DEBUG_LEVEL > 0
01204   std::cout << "weights_CRSA + lambda =" << std::endl;
01205   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01206     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01207   }
01208   std::cout << std::endl;
01209   #endif
01210
01212
01213   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01214
01215     int minrow_{std::numeric_limits<int>::infinity()};
01216
01217     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01218     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01219
01221
01222     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01223
01224     // 6.1. Insert preliminary approximations to first set of columns.
01225
01226     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01227       for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01228         phi.data()[ii*(order_accuracy_) + jj] =
01229           prem_apps_[ii*num_bndy_approxs_ + jj];
01230       }
01231     }
01232
01233     // 6.2. Skip a column and negate preliminary approximations.
01234
01235     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01236       for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01237         auto de = (ii+ order_accuracy_ - num_bndy_approxs_+ jj*order_accuracy_);
01238         auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01239         phi.data()[de] = -prem_apps_[og];
01240       }
01241     }
```

```
01242
01243     // 6.3. Flip negative columns up-down.
01244
01245     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01246       for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01247         auto aux = phi.data()[ii*order_accuracy_ + jj];
01248         phi.data()[ii*order_accuracy_ + jj] =
01249           phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj];
01250         phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01251       }
01252     }
01253
01254     // 6.4. Insert stencil.
01255
01256     auto mm = 0;
01257     for (auto jj = num_bndy_approxs_; jj < num_bndy_approxs_ +  1; jj++) {
01258       for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01259         if (ii == 0) {
01260           phi.data()[jj] = 0.0;
01261         } else {
01262           phi.data()[(ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01263         }
01264       }
01265       mm++;
01266     }
01267
01268     #if MTK_DEBUG_LEVEL > 0
01269     std::cout << "phi =" << std::endl;
01270     std::cout << phi << std::endl;
01271     #endif
01272
01274
01275     mtk::Real *lamed{};  // Used to build big lambda.
01276
01277     try {
01278       lamed = new mtk::Real[num_bndy_approxs_ - 1];
01279     } catch (std::bad_alloc &memory_allocation_exception) {
01280       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01281         std::endl;
01282       std::cerr << memory_allocation_exception.what() << std::endl;
01283     }
01284     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01285
01286     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01287       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01288     }
01289
01290     #if MTK_DEBUG_LEVEL > 0
01291     std::cout << "lamed =" << std::endl;
01292     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01293       std::cout << std::setw(12) << lamed[ii] << std::endl;
01294     }
01295     std::cout << std::endl;
01296     #endif
01297
01298     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01299       mtk::Real temp = mtk::kZero;
01300       for(auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01301         temp = temp +
01302           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01303       }
01304       hh[ii] = hh[ii] - temp;
01305     }
01306
01307     #if MTK_DEBUG_LEVEL > 0
01308     std::cout << "big_lambda =" << std::endl;
01309     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01310       std::cout << std::setw(12) << hh[ii] << std::endl;
01311     }
01312     std::cout << std::endl;
01313     #endif
01314
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.
    data(),
01323                                                           order_accuracy_ + 1,
```

```
01324                                                       order_accuracy_,
01325                                                       order_accuracy_,
01326                                                       hh,
01327                                                       weights_cbs_,
01328                                                       row_,
01329                                                       mimetic_threshold_,
01330                                                       copy_result);
01331       mtk::Real aux{normerr_/norm};
01332
01333       #if MTK_DEBUG_LEVEL>0
01334       std::cout << "Relative norm: " << aux << " " << std::endl;
01335       std::cout << std::endl;
01336       #endif
01337
01338       if (aux < minnorm) {
01339         minnorm = aux;
01340         minrow_= row_;
01341       }
01342     }
01343
01344     #if MTK_DEBUG_LEVEL > 0
01345     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01346       std::endl;
01347     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01348       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01349     }
01350     std::cout << std::endl;
01351     #endif
01352
01354
01355     // After we know which row yields the smallest relative norm that row is
01356     // chosen to be the objective function and the result of the optimizer is
01357     // chosen to be the new weights_.
01358
01359     #if MTK_DEBUG_LEVEL > 0
01360     std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01361       minrow_ + 1 << std::endl;
01362     std::cout << std::endl;
01363     #endif
01364
01365     copy_result = 1;
01366     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01367                                                         order_accuracy_ + 1,
01368                                                         order_accuracy_,
01369                                                         order_accuracy_,
01370                                                         hh,
01371                                                         weights_cbs_,
01372                                                         minrow_,
01373                                                         mimetic_threshold_,
01374                                                         copy_result);
01375     mtk::Real aux_{normerr_/norm};
01376     #if MTK_DEBUG_LEVEL > 0
01377     std::cout << "Relative norm: " << aux_ << std::endl;
01378     std::cout << std::endl;
01379     #endif
01380
01381     delete [] lamed;
01382     lamed = nullptr;
01383   }
01384
01385   delete [] hh;
01386   hh = nullptr;
01387
01388   return true;
01389 }
01390
01391 bool mtk::Grad1D::ComputeStencilBoundaryGrid(void) {
01392
01393   #if MTK_DEBUG_LEVEL > 0
01394   std::cout << "weights_* + lambda =" << std::endl;
01395   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01396     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01397   }
01398   std::cout << std::endl;
01399   #endif
01400
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
01427
01428   mtk::Real *alpha{}; // Collection of alpha values.
01429
01430   try {
01431     alpha = new mtk::Real[dim_null_];
01432   } catch (std::bad_alloc &memory_allocation_exception) {
01433     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01434       std::endl;
01435     std::cerr << memory_allocation_exception.what() << std::endl;
01436   }
01437   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01438
01439   for (auto ii = 0; ii < dim_null_; ++ii) {
01440     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01441   }
01442
01443   #if MTK_DEBUG_LEVEL > 0
01444   std::cout << "alpha =" << std::endl;
01445   for (auto ii = 0; ii < dim_null_; ++ii) {
01446     std::cout << std::setw(12) << alpha[ii] << std::endl;
01447   }
01448   std::cout << std::endl;
01449   #endif
01450
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;
```

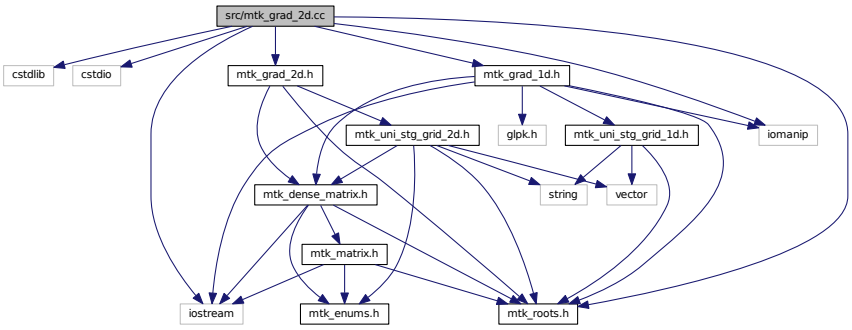
```
01489   lambda = nullptr;
01490
01491   delete[] alpha;
01492   alpha = nullptr;
01493
01494   return true;
01495 }
01496
01497 bool mtk::Grad1D::AssembleOperator(void) {
01498
01499   // The output array will have this form:
01500   // 1. The first entry of the array will contain the used order 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   memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01522
01524
01525   gradient_[0] = order_accuracy_;
01526
01529
01530   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01531     gradient_[ii + 1] = coeffs_interior_[ii];
01532   }
01533
01535
01536   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01537     gradient_[(order_accuracy_ + 1) + ii] = weights_cbs_[ii];
01538   }
01539
01542
01543   int offset{2*order_accuracy_ + 1};
01544
01545   int aux {}; // Auxiliary variable.
01546
01547   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01548     for (auto ii = 0; ii < num_bndy_approxs_ ; ii++) {
01549       for (auto jj = 0; jj < num_bndy_coeffs_; jj++) {
01550         gradient_[offset + aux] = mim_bndy_[jj*num_bndy_approxs_ + ii];
01551         aux++;
01552       }
01553     }
01554   } else {
01555     gradient_[offset + 0] = prem_apps_[0];
01556     gradient_[offset + 1] = prem_apps_[1];
01557     gradient_[offset + 2] = prem_apps_[2];
01558   }
01559
01560   #if MTK_DEBUG_LEVEL > 0
01561   std::cout << "1D " << order_accuracy_ << "-order grad built!" << std::endl;
01562   std::cout << std::endl;
01563   #endif
01564
01565   return true;
01566 }
```

## 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**

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

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
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 <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_2d.h"
00066
00067 mtk::Grad2D::Grad2D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Grad2D::Grad2D(const Grad2D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad2D::~Grad2D() {}
00076
00077 bool mtk::Grad2D::ConstructGrad2D(const
      mtk::UniStgGrid2D &grid,
00078                                   int order_accuracy,
00079                                   mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083
00084   int mx = num_cells_x + 1;  // Gx vertical dimension
00085   int nx = num_cells_x + 2;  // Gx horizontal dimension
00086   int my = num_cells_y + 1;  // Gy vertical dimension
00087   int ny = num_cells_y + 2;  // Gy horizontal dimension
00088
00089   mtk::Grad1D grad;
00090
00091   bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00092
00093   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.east_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);
```

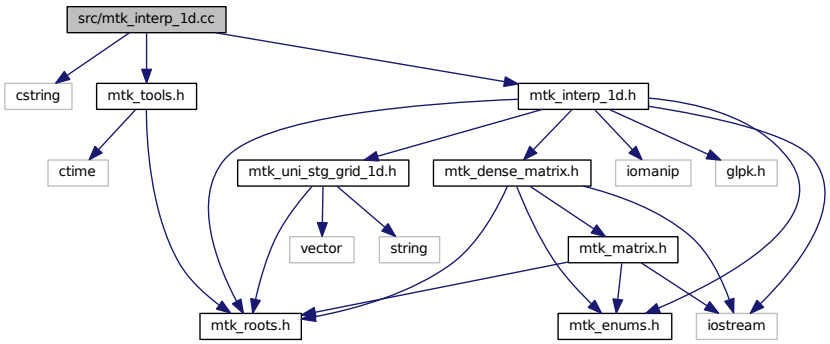
```
00113   mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00114
00115   mtk::DenseMatrix gxy(mtk::DenseMatrix::Kron(tiy, Gx));
00116   mtk::DenseMatrix gyx(mtk::DenseMatrix::Kron(Gy, tix));
00117
00118   #if MTK_DEBUG_LEVEL > 0
00119   std::cout << "Gx :" << mx << "by " << nx << std::endl;
00120   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 << "Kronecker dimensions Grad 2D" <<
00124     mx*num_cells_y + my*num_cells_x << " by " <<  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() {
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 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #include <cstring>
```

```
00059
00060 #include "mtk_tools.h"
00061
00062 #include "mtk_interp_1d.h"
00063
00064 namespace mtk {
00065
00066 std::ostream& operator <<(std::ostream &stream, mtk::Interp1D &in) {
00067
00069
00070   stream << "coeffs_interior_[1:" << in.order_accuracy_ << "] = ";
00071   for (auto ii = 0; ii < in.order_accuracy_; ++ii) {
00072     stream << std::setw(9) << in.coeffs_interior_[ii] << " ";
00073   }
00074   stream << std::endl;
00075
00076   return stream;
00077 }
00078 }
00079
00080 mtk::Interp1D::Interp1D():
00081   dir_interp_(mtk::SCALAR_TO_VECTOR),
00082   order_accuracy_(mtk::kDefaultOrderAccuracy),
00083   coeffs_interior_(nullptr) {}
00084
00085 mtk::Interp1D::Interp1D(const Interp1D &interp):
00086   dir_interp_(interp.dir_interp_),
00087   order_accuracy_(interp.order_accuracy_),
00088   coeffs_interior_(interp.coeffs_interior_) {}
00089
00090 mtk::Interp1D::~Interp1D() {
00091
00092   delete[] coeffs_interior_;
00093   coeffs_interior_ = nullptr;
00094 }
00095
00096 bool mtk::Interp1D::ConstructInterp1D(int order_accuracy,
      mtk::DirInterp dir) {
00097
00098   #if MTK_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
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(const
       UniStgGrid1D &grid) {
00136
00137   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00138
00139   #if MTK_DEBUG_LEVEL > 0
```

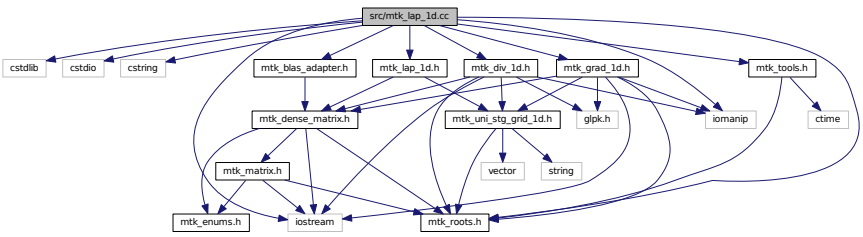
```
00140   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00141   #endif
00142
00143   int gg_num_rows{};  // Number of rows.
00144   int gg_num_cols{};  // Number of columns.
00145
00146   if (dir_interp_ == mtk::SCALAR_TO_VECTOR) {
00147     gg_num_rows = nn + 1;
00148     gg_num_cols = nn + 2;
00149   } else {
00150     gg_num_rows = nn + 2;
00151     gg_num_cols = nn + 1;
00152   }
00153
00154   // Output matrix featuring sizes for gradient operators.
00155
00156   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00157
00159
00160   out.SetValue(0, 0, mtk::kOne);
00161
00163
00164   for (auto ii = 1; ii < gg_num_rows - 1; ++ii) {
00165     for(auto jj = ii ; jj < order_accuracy_ + ii; ++jj) {
00166       out.SetValue(ii, jj, mtk::kOne/order_accuracy_);
00167     }
00168   }
00169
00171
00172   out.SetValue(gg_num_rows - 1, gg_num_cols - 1, mtk::kOne);
00173
00174   return out;
00175 }
```

## 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
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 <cstdlib>
00058 #include <cstdio>
00059 #include <cstring>
00060
00061 #include <iostream>
00062 #include <iomanip>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_tools.h"
00066 #include "mtk_blas_adapter.h"
00067 #include "mtk_grad_1d.h"
00068 #include "mtk_div_1d.h"
00069 #include "mtk_lap_1d.h"
00070
00071 namespace mtk {
00072
00073 std::ostream& operator <<(std::ostream &stream, mtk::Lap1D &in) {
00074
00076
00077   stream << "laplacian_[0] = " << in.laplacian_[0] << std::endl << std::endl;
00078
00080
00081   stream << "laplacian_[1:" << 2*in.order_accuracy_ - 1 << "] = " <<
00082     std::endl << std::endl;
00083   for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00084     stream << std::setw(13) << in.laplacian_[ii] << " ";
00085   }
00086   stream << std::endl << std::endl;
00087
00089
00090   auto offset = 1 + (2*in.order_accuracy_ - 1);
00091
00092   stream << "laplacian_[" << offset << ":" << offset +
00093     (in.order_accuracy_ - 1)*(2*in.order_accuracy_) - 1 << "] = " <<
00094     std::endl << std::endl;
00095
00096   for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00097     for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00098       stream << std::setw(13) <<
00099         in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00100     }
00101     stream << std::endl;
00102   }
00103
00104   return stream;
00105 }
00106 }
00107
00108 mtk::Lap1D::Lap1D():
00109   order_accuracy_(mtk::kDefaultOrderAccuracy),
00110   laplacian_length_(),
00111   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
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
00151
00152   mtk::Div1D div; // Mimetic divergence.
00153
00154   info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00155
00156   if (!info) {
00157     std::cerr << "Mimetic div could not be built." << std::endl;
00158     return false;
00159   }
00160
00162
00163   // Since these are mimetic operator, we must multiply the matrices arising
00164   // from both the divergence and the Laplacian, in order to get the
00165   // approximating coefficients for the Laplacian operator.
00166
00167   // However, we must choose a grid that implied a step size of 1, so to get
00168   // the approximating coefficients, without being affected from the
00169   // normalization with respect to the grid.
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
00216   // The output array will have this form:
00217   // 1. The first entry of the array will contain the used order kk.
00218   // 2. The second entry of the array will contain the collection of
00219   // approximating coefficients for the interior of the grid.
00220   // 3. The next entries will contain the collections of approximating
00221   // coefficients for the west boundary of the grid.
00222
00223   laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00224     (order_accuracy_ - 1)*(2*order_accuracy_);
00225
```

```
00226   #if MTK_DEBUG_LEVEL > 0
00227   std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00228   std::cout << std::endl;
00229   #endif
00230
00231   try {
00232     laplacian_ = new mtk::Real[laplacian_length_];
00233   } catch (std::bad_alloc &memory_allocation_exception) {
00234     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00235       std::endl;
00236     std::cerr << memory_allocation_exception.what() << std::endl;
00237   }
00238   memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00239
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::Lap1D::ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) {
00266
00267   int nn{grid.num_cells_x()};  // Number of cells on the grid.
00268
00269   #if MTK_DEBUG_LEVEL > 0
00270   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00271   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00272   #endif
00273
00274   mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00275
00276   mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
       dx^2.
00277
00279
00280   auto offset = (1 + 2*order_accuracy_ - 1);
00281
00282   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00283     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00284       lap.SetValue(1 + ii,
00285                    jj,
00286                    idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00287     }
00288   }
00289
00291
00292   offset = 1 + (order_accuracy_ - 1);
00293
00294   int kk{1};
00295   for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00296     int mm{1};
00297     for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00298       lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00299       mm = mm + 1;
00300     }
00301     kk = kk + 1;
00302   }
00303
00305
00306   offset = (1 + 2*order_accuracy_ - 1);
00307
00308   auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00309
00310   auto ll = 1;
00311   auto rr = 1;
```

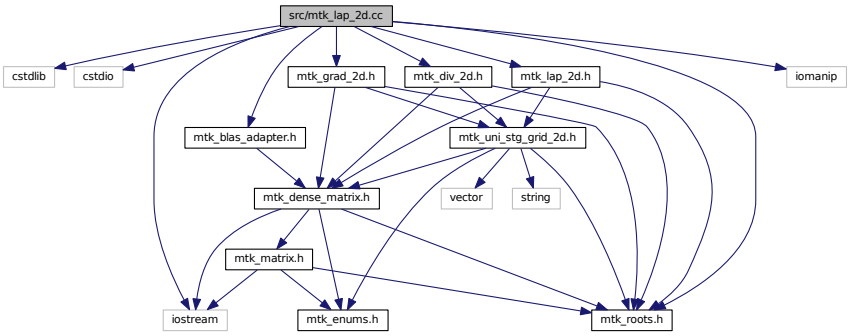
```
00312   for (auto ii = nn; ii > aux - 1; --ii) {
00313     auto cc = 0;
00314     for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00315       lap.SetValue(ii, jj, lap.GetValue(rr,cc));
00316       ++ll;
00317       ++cc;
00318     }
00319     rr++;
00320   }
00321
00328
00329   return lap;
00330 }
00331
00332 mtk::Real* mtk::Lap1D::data(const UniStgGrid1D &grid) {
00333
00334   mtk::DenseMatrix tmp;
00335
00336   tmp = ReturnAsDenseMatrix(grid);
00337
00338   return tmp.data();
00339 }
```

## 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

```
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 <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_blas_adapter.h"
00065 #include "mtk_grad_2d.h"
00066 #include "mtk_div_2d.h"
00067 #include "mtk_lap_2d.h"
00068
00069 mtk::Lap2D::Lap2D(): order_accuracy_(), mimetic_threshold_() {}
00070
00071 mtk::Lap2D::Lap2D(const Lap2D &lap):
00072   order_accuracy_(lap.order_accuracy_),
00073   mimetic_threshold_(lap.mimetic_threshold_) {}
00074
00075 mtk::Lap2D::~Lap2D() {}
00076
00077 bool mtk::Lap2D::ConstructLap2D(const
```

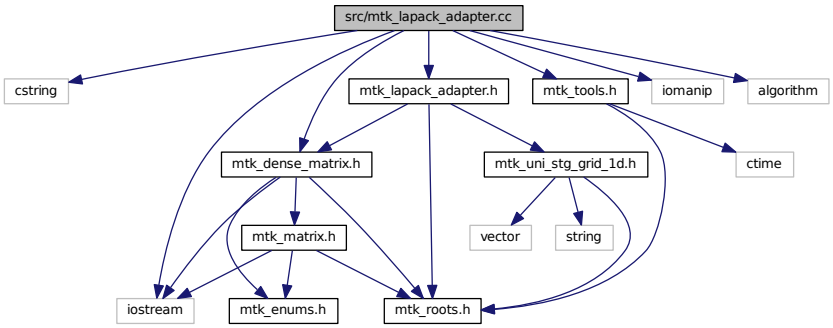
```
      mtk::UniStgGrid2D &grid,
00078                                 int order_accuracy,
00079                                 mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x{grid.num_cells_x()};
00082   int num_cells_y{grid.num_cells_y()};
00083   int aux{(num_cells_x + 2)*(num_cells_y + 2)};
00084
00085   mtk::Grad2D gg;
00086   mtk::Div2D dd;
00087
00088   bool info{gg.ConstructGrad2D(grid, order_accuracy, mimetic_threshold)};
00089
00090   if (!info) {
00091     std::cerr << "Mimetic lap could not be built." << std::endl;
00092     return info;
00093   }
00094
00095   info = dd.ConstructDiv2D(grid, order_accuracy, mimetic_threshold);
00096
00097   if (!info) {
00098     std::cerr << "Mimetic div could not be built." << std::endl;
00099     return info;
00100   }
00101
00102   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00103   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00104
00105   laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00106
00107   return info;
00108 }
00109
00110 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix() {
00111
00112   return laplacian_;
00113 }
00114
00115 mtk::Real* mtk::Lap2D::data() {
00116
00117   return laplacian_.data();
00118 }
```

## 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

```
00001
00021 /*
00022 Copyright (C) 2015, Computational Science Research Center, San Diego State
00023 University. All rights reserved.
00024
00025 Redistribution and use in source and binary forms, with or without modification,
00026 are permitted provided that the following conditions are met:
00027
00028 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00029 and a copy of the modified files should be reported once modifications are
00030 completed, unless these modifications are made through the project's GitHub
00031 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00032 should be developed and included in any deliverable.
00033
00034 2. Redistributions of source code must be done through direct
00035 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00036
00037 3. Redistributions in binary form must reproduce the above copyright notice,
00038 this list of conditions and the following disclaimer in the documentation and/or
00039 other materials provided with the distribution.
00040
00041 4. Usage of the binary form on proprietary applications shall require explicit
00042 prior written permission from the the copyright holders, and due credit should
00043 be given to the copyright holders.
00044
00045 5. Neither the name of the copyright holder nor the names of its contributors
00046 may be used to endorse or promote products derived from this software without
00047 specific prior written permission.
00048
00049 The copyright holders provide no reassurances that the source code provided does
00050 not infringe any patent, copyright, or any other intellectual property rights of
00051 third parties. The copyright holders disclaim any liability to any recipient for
00052 claims brought against recipient by any third party for infringement of that
00053 parties intellectual property rights.
00054
00055 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00056 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00057 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00058 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00059 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00060 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00061 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00062 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00063 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00064 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00065 */
00066
00067 #include <cstring>
00068
00069 #include <iostream>
00070 #include <iomanip>
00071
00072 #include <algorithm>
00073
00074 #include "mtk_tools.h"
00075 #include "mtk_dense_matrix.h"
00076 #include "mtk_lapack_adapter.h"
00077
00078 namespace mtk {
00079
00080 extern "C" {
00081
00082 #ifdef MTK_PRECISION_DOUBLE
00083
00102 void dgesv_(int* n,
00103             int* nrhs,
00104             Real* a,
00105             int* lda,
```

```
00106             int* ipiv,
00107             Real* b,
00108             int* ldb,
00109             int* info);
00110 #else
00111
00130 void sgesv_(int* n,
00131             int* nrhs,
00132             Real* a,
00133             int* lda,
00134             int* ipiv,
00135             Real* b,
00136             int* ldb,
00137             int* info);
00138 #endif
00139
00140 #ifdef MTK_PRECISION_DOUBLE
00141
00184 void dgels_(char* trans,
00185             int* m,
00186             int* n,
00187             int* nrhs,
00188             Real* a,
00189             int* lda,
00190             Real* b,
00191             int* ldb,
00192             Real* work,
00193             int* lwork,
00194             int* info);
00195 #else
00196
00239 void sgels_(char* trans,
00240             int* m,
00241             int* n,
00242             int* nrhs,
00243             Real* a,
00244             int* lda,
00245             Real* b,
00246             int* ldb,
00247             Real* work,
00248             int* lwork,
00249             int* info);
00250 #endif
00251
00252 #ifdef MTK_PRECISION_DOUBLE
00253
00282 void dgeqrf_(int *m,
00283              int *n,
00284              Real *a,
00285              int *lda,
00286              Real *tau,
00287              Real *work,
00288              int *lwork,
00289              int *info);
00290 #else
00291
00320 void sgeqrf_(int *m,
00321              int *n,
00322              Real *a,
00323              int *lda,
00324              Real *tau,
00325              Real *work,
00326              int *lwork,
00327              int *info);
00328 #endif
00329
00330 #ifdef MTK_PRECISION_DOUBLE
00331
00365 void dormqr_(char *side,
00366              char *trans,
00367              int *m,
00368              int *n,
00369              int *k,
00370              Real *a,
00371              int *lda,
00372              Real *tau,
00373              Real *c,
00374              int *ldc,
00375              Real *work,
00376              int *lwork,
00377              int *info);
```

```
00378 #else
00379
00413 void sormqr_(char *side,
00414              char *trans,
00415              int *m,
00416              int *n,
00417              int *k,
00418              Real *a,
00419              int *lda,
00420              Real *tau,
00421              Real *c,
00422              int *ldc,
00423              Real *work,
00424              int *lwork,
00425              int *info);
00426 #endif
00427 }
00428 }
00429
00430 int mtk::LAPACKAdapter::SolveDenseSystem(
     mtk::DenseMatrix &mm,
00431                                          mtk::Real *rhs) {
00432
00433   #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,
00466                                          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,
00518                                          mtk::UniStgGrid1D &rhs) {
00519
00520   int nrhs{1};  // Number of right-hand sides.
00521
00522   int *ipiv{};               // Array for pivoting information.
00523   int info{};                // Status of the solution.
00524   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00525
00526   try {
00527     ipiv = new int[mm_rank];
00528   } catch (std::bad_alloc &memory_allocation_exception) {
00529     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00530       std::endl;
00531     std::cerr << memory_allocation_exception.what() << std::endl;
00532   }
00533   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00534
00535   int ldbb = mm_rank;
00536   int mm_ld = mm_rank;
00537
00538   mm.OrderColMajor();
00539
00540   #ifdef MTK_PRECISION_DOUBLE
00541   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00542          rhs.discrete_field_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
00661   bool transpose{false};
00662
00663   mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00664
00665   #if MTK_DEBUG_LEVEL > 0
00666   std::cout << "Initialized QQ_T: " << std::endl;
00667   std::cout << QQ_ << std::endl;
00668   #endif
00669
00670   // Assemble the QQ_ matrix:
00671   lwork = -1;
00672
00673   delete[] work;
00674   work = nullptr;
00675
00676   try {
00677     work = new mtk::Real[1];
00678   } catch (std::bad_alloc &memory_allocation_exception) {
00679     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00680       std::endl;
00681     std::cerr << memory_allocation_exception.what() <<
00682       std::endl;
00683   }
00684   memset(work, mtk::kZero, sizeof(work[0])*1);
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,
00757                                                     mtk::Real *ob_,
00758                                                     int ob_ld_) {
00759
00760   // We first invoke the solver to query for the value of lwork. For this,
00761   // we must at least allocate enough space to allow access to WORK(1), or
00762   // work[0]:
00763
00764   // If LWORK = -1, then a workspace query is assumed; the routine only
00765   // calculates the optimal size of the WORK array, returns this value as
00766   // the first entry of the WORK array, and no error message related to
00767   // LWORK is issued by XERBLA.
00768
00769   mtk::Real *work{}; // Work array.
00770
00771   try {
00772     work = new mtk::Real[1];
00773   } catch (std::bad_alloc &memory_allocation_exception) {
00774     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00775     std::cerr << memory_allocation_exception.what() << std::endl;
00776   }
00777   memset(work, mtk::kZero, sizeof(work[0])*1);
00778
00779   char trans_{'N'};
00780   int nrhs_{1};
00781   int info{0};
00782   int lwork{-1};
00783
00784   int AA_num_rows_  = aa.num_cols();
00785   int AA_num_cols_  = aa.num_rows();
00786   int AA_ld_ = std::max(1,aa.num_cols());
00787
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
```

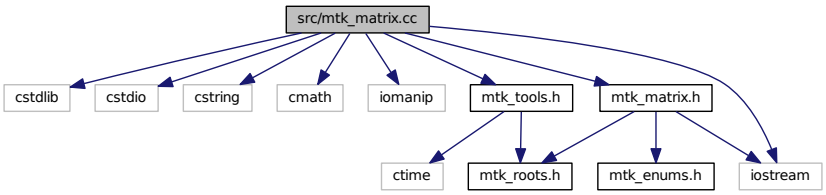
```
00811
00812   // We then use lwork's new value to create the work array:
00813   delete[] work;
00814   work = nullptr;
00815
00816   try {
00817     work = new mtk::Real[lwork];
00818   } catch (std::bad_alloc &memory_allocation_exception) {
00819     std::cerr << "Memory allocation exception on 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 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <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() {}
00106
00107 mtk::MatrixStorage mtk::Matrix::storage() const {
00108
00109   return storage_;
00110 }
00111
00112 mtk::MatrixOrdering mtk::Matrix::ordering() const {
00113
00114   return ordering_;
00115 }
00116
00117 int mtk::Matrix::num_rows() const {
00118
00119   return num_rows_;
00120 }
00121
00122 int mtk::Matrix::num_cols() const {
00123
00124   return num_cols_;
00125 }
00126
00127 int mtk::Matrix::num_values() const {
00128
00129   return num_values_;
00130 }
00131
00132 int mtk::Matrix::ld() const {
00133
00134   return ld_;
00135 }
00136
00137 int mtk::Matrix::num_zero() const {
00138
00139   return num_zero_;
00140 }
00141
00142 int mtk::Matrix::num_non_zero() const {
00143
00144   return num_non_zero_;
00145 }
00146
00147 int mtk::Matrix::num_null() const {
00148
00149   return num_null_;
00150 }
00151
00152 int mtk::Matrix::num_non_null() const {
00153
00154   return num_non_null_;
00155 }
00156
00157 int mtk::Matrix::kl() const {
```

```
00158
00159   return kl_;
00160 }
00161
00162 int mtk::Matrix::ku() const {
00163
00164   return ku_;
00165 }
00166
00167 int mtk::Matrix::bandwidth() const {
00168
00169   return bandwidth_;
00170 }
00171
00172 mtk::Real mtk::Matrix::rel_density() const {
00173
00174   return rel_density_;
00175 }
00176
00177 mtk::Real mtk::Matrix::abs_sparsity() const {
00178
00179   return abs_sparsity_;
00180 }
00181
00182 mtk::Real mtk::Matrix::rel_sparsity() const {
00183
00184   return rel_sparsity_;
00185 }
00186
00187 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss) {
00188
00189   #if MTK_DEBUG_LEVEL > 0
00190   mtk::Tools::Prevent(!(ss == mtk::DENSE ||
00191                         ss == mtk::BANDED ||
00192                         ss == mtk::CRS),
00193                       __FILE__, __LINE__, __func__);
00194   #endif
00195
00196   storage_ = ss;
00197 }
00198
00199 void mtk::Matrix::set_ordering(const
      mtk::MatrixOrdering &oo) {
00200
00201   #if MTK_DEBUG_LEVEL > 0
00202   mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
      mtk::COL_MAJOR),
00203                       __FILE__, __LINE__, __func__);
00204   #endif
00205
00206   ordering_ = oo;
00207
00208   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00209     std::max(1,num_cols_): std::max(1,num_rows_);
00210 }
00211
00212 void mtk::Matrix::set_num_rows(int in) {
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(int in) {
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(int in) {
```

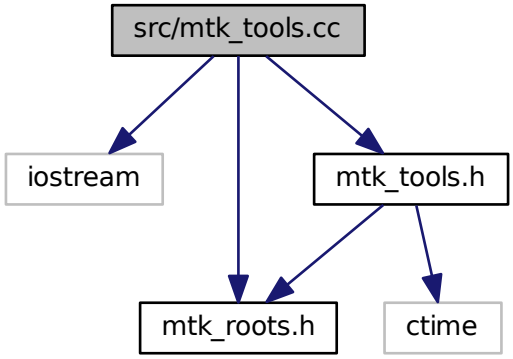
```
00237
00238   #if MTK_DEBUG_LEVEL > 0
00239   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00240   #endif
00241
00242   num_zero_ = in;
00243   num_non_zero_ = num_values_ - num_zero_;
00244
00246   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00247   rel_sparsity_ = 1.0 - rel_density_;
00248 }
00249
00250 void mtk::Matrix::set_num_null(int in) {
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
00260   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00261   abs_sparsity_ = 1.0 - abs_density_;
00262 }
00263
00264 void mtk::Matrix::IncreaseNumZero() {
00265
00267
00268   num_zero_++;
00269   num_non_zero_ = num_values_ - num_zero_;
00270   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00271   rel_sparsity_ = 1.0 - rel_density_;
00272 }
00273
00274 void mtk::Matrix::IncreaseNumNull() {
00275
00277
00278   num_null_++;
00279   num_non_null_ = num_values_ - num_null_;
00280   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00281   abs_sparsity_ = 1.0 - abs_density_;
00282 }
```

## 17.81 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 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
```

```
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057
00058 #include "mtk_roots.h"
00059 #include "mtk_tools.h"
00060
00061 void mtk::Tools::Prevent(const bool condition,
00062                          const char *fname,
00063                          int lineno,
00064                          const char *fxname) {
00065
00067
00068   #if MTK_DEBUG_LEVEL > 0
00069   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
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) {
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) {
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) {
00115
00116   if (condition) {
00117     std::cout << "Test " << test_number_ << ": PASSED in " << duration_ <<
00118       " s." << std::endl;
```

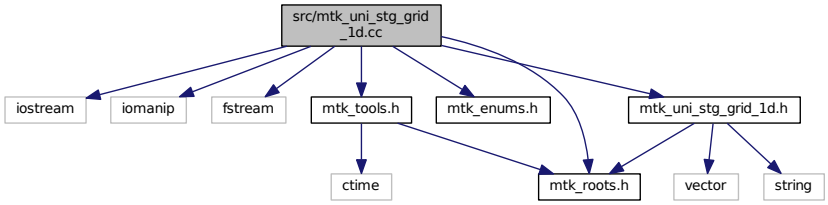
```
00119   } else {
00120     std::cout << "Test " << test_number_ << ": FAILED in " << duration_ <<
00121       " s." << std::endl;
00122   }
00123 }
```

## 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

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_enums.h"
00062 #include "mtk_tools.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00068 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid1D &in) {
00069
00070   stream << '[' << in.west_bndy_x_ << ':' << in.num_cells_x_ << ':' <<
00071   in.east_bndy_x_ << "] = " << std::endl << std::endl;
00072
00074
00075   stream << "x:";
00076   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00077     stream << std::setw(10) << in.discrete_domain_x_[ii];
00078   }
00079   stream << std::endl;
00080
00082
00083   if (in.nature_ == mtk::SCALAR) {
00084     stream << "u:";
00085   }
00086   else {
00087     stream << "v:";
00088   }
```

```
00089   for (unsigned int ii = 0; ii < in.discrete_field_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
      UniStgGrid1D &grid):
00109     nature_(grid.nature_),
00110     west_bndy_x_(grid.west_bndy_x_),
00111     east_bndy_x_(grid.east_bndy_x_),
00112     num_cells_x_(grid.num_cells_x_),
00113     delta_x_(grid.delta_x_) {
00114
00115     std::copy(grid.discrete_domain_x_.begin(),
00116               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00117               discrete_domain_x_.begin());
00118
00119     std::copy(grid.discrete_field_u_.begin(),
00120               grid.discrete_field_u_.begin() + grid.
      discrete_field_u_.size(),
00121               discrete_field_u_.begin());
00122 }
00123
00124 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00125                                 const Real &east_bndy_x,
00126                                 const int &num_cells_x,
00127                                 const mtk::FieldNature &nature) {
00128
00129   #if MTK_DEBUG_LEVEL > 0
00130   mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00131   mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00132   mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00133   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00134   #endif
00135
00136   nature_ = nature;
00137   west_bndy_x_ = west_bndy_x;
00138   east_bndy_x_ = east_bndy_x;
00139   num_cells_x_ = num_cells_x;
00140
00141   delta_x_ = (east_bndy_x - west_bndy_x)/((mtk::Real) num_cells_x);
00142 }
00143
00144 mtk::UniStgGrid1D::~UniStgGrid1D() {}
00145
00146 mtk::Real mtk::UniStgGrid1D::west_bndy_x() const {
00147
00148   return west_bndy_x_;
00149 }
00150
00151 mtk::Real mtk::UniStgGrid1D::east_bndy_x() const {
00152
00153   return east_bndy_x_;
00154 }
00155
00156 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00157
00158   return delta_x_;
00159 }
00160
00161 mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() {
00162
00163   return discrete_domain_x_.data();
00164 }
00165
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
00184
00185   discrete_domain_x_.reserve(num_cells_x_ + 2);
00186
00187   discrete_domain_x_.push_back(west_bndy_x_);
00188   #ifdef MTK_PRECISION_DOUBLE
00189   auto first_center = west_bndy_x_ + delta_x_/2.0;
00190   #else
00191   auto first_center = west_bndy_x_ + delta_x_/2.0f;
00192   #endif
00193   discrete_domain_x_.push_back(first_center);
00194   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00195     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00196   }
00197   discrete_domain_x_.push_back(east_bndy_x_);
00198
00200
00201   discrete_field_u_.reserve(num_cells_x_ + 2);
00202
00203   discrete_field_u_.push_back(ScalarField(west_bndy_x_));
00204
00205   discrete_field_u_.push_back(ScalarField(first_center));
00206   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00207     discrete_field_u_.push_back(ScalarField(first_center + ii*delta_x_));
00208   }
00209   discrete_field_u_.push_back(ScalarField(east_bndy_x_));
00210 }
00211
00212 void mtk::UniStgGrid1D::BindVectorField(
00213     mtk::Real (*VectorField)(mtk::Real xx)) {
00214
00215   #if MTK_DEBUG_LEVEL > 0
00216   mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00217   #endif
00218
00220
00221   discrete_domain_x_.reserve(num_cells_x_ + 1);
00222
00223   discrete_domain_x_.push_back(west_bndy_x_);
00224   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00225     discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00226   }
00227   discrete_domain_x_.push_back(east_bndy_x_);
00228
00230
00231   discrete_field_u_.reserve(num_cells_x_ + 1);
00232
00233   discrete_field_u_.push_back(VectorField(west_bndy_x_));
00234   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00235     discrete_field_u_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00236   }
00237   discrete_field_u_.push_back(VectorField(east_bndy_x_));
00238 }
00239
00240 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00241                                     std::string space_name,
00242                                     std::string field_name) {
00243
00244   std::ofstream output_dat_file;  // Output file.
00245
00246   output_dat_file.open(filename);
00247
00248   if (!output_dat_file.is_open()) {
00249     return false;
00250   }
00251
```

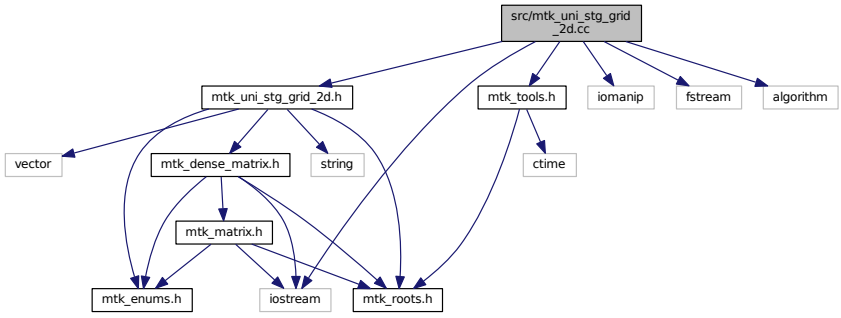
```
00252   output_dat_file << "# " << space_name <<  ' ' << field_name << std::endl;
00253   for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00254     output_dat_file << discrete_domain_x_[ii] << ' ' << discrete_field_u_[ii] <<
00255       std::endl;
00256   }
00257
00258   output_dat_file.close();
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 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include <algorithm>
00061
00062 #include "mtk_tools.h"
00063 #include "mtk_uni_stg_grid_2d.h"
00064
00065 namespace mtk {
00066
00067 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid2D &in) {
00068
00069   stream << '[' << in.west_bndy_ << ':' << in.num_cells_x_ << ':' <<
00070   in.east_bndy_ << "] x ";
00071
00072   stream << '[' << in.south_bndy_ << ':' << in.num_cells_y_ << ':' <<
00073   in.north_bndy_ << "] = " << std::endl << std::endl;
00074
00076
00077   stream << "x:";
```

```
00078   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00079     stream << std::setw(10) << in.discrete_domain_x_[ii];
00080   }
00081   stream << std::endl;
00082
00083   stream << "y:";
00084   for (unsigned int ii = 0; ii < in.discrete_domain_y_.size(); ++ii) {
00085     stream << std::setw(10) << in.discrete_domain_y_[ii];
00086   }
00087   stream << std::endl;
00088
00090
00091   if (in.nature_ == mtk::SCALAR) {
00092     stream << "u:" << std::endl;
00093     if (in.discrete_field_.size() > 0) {
00094       for (int ii = 0; ii < in.num_cells_x_ + 2; ++ii) {
00095         for (int jj = 0; jj < in.num_cells_y_ + 2; ++jj) {
00096           stream << std::setw(10) << in.discrete_field_[ii*in.
      num_cells_y_ + jj];
00097         }
00098         stream << std::endl;
00099       }
00100     }
00101   } else {
00102
00103     int mm{in.num_cells_x_};
00104     int nn{in.num_cells_y_};
00105     int p_offset{nn*(mm + 1) - 1};
00106
00107     stream << "p(x,y):" << std::endl;
00108     for (int ii = 0; ii < nn; ++ii) {
00109       for (int jj = 0; jj < mm + 1; ++jj) {
00110         stream << std::setw(10) << in.discrete_field_[ii*(mm + 1) + jj];
00111       }
00112       stream << std::endl;
00113     }
00114     stream << std::endl;
00115
00116     stream << "q(x,y):" << std::endl;
00117     for (int ii = 0; ii < nn + 1; ++ii) {
00118       for (int jj = 0; jj < mm; ++jj) {
00119         stream << std::setw(10) <<
00120           in.discrete_field_[p_offset + ii*mm + jj];
00121       }
00122       stream << std::endl;
00123     }
00124     stream << std::endl;
00125   }
00126
00127   return stream;
00128 }
00129 }
00130
00131 mtk::UniStgGrid2D::UniStgGrid2D():
00132     discrete_domain_x_(),
00133     discrete_domain_y_(),
00134     discrete_field_(),
00135     nature_(),
00136     west_bndy_(),
00137     east_bndy_(),
00138     num_cells_x_(),
00139     delta_x_(),
00140     south_bndy_(),
00141     north_bndy_(),
00142     num_cells_y_(),
00143     delta_y_() {}
00144
00145 mtk::UniStgGrid2D::UniStgGrid2D(const
      UniStgGrid2D &grid):
00146     nature_(grid.nature_),
00147     west_bndy_(grid.west_bndy_),
00148     east_bndy_(grid.east_bndy_),
00149     num_cells_x_(grid.num_cells_x_),
00150     delta_x_(grid.delta_x_),
00151     south_bndy_(grid.south_bndy_),
00152     north_bndy_(grid.north_bndy_),
00153     num_cells_y_(grid.num_cells_y_),
00154     delta_y_(grid.delta_y_) {
00155
00156     std::copy(grid.discrete_domain_x_.begin(),
00157               grid.discrete_domain_x_.begin() + grid.
```

```
    discrete_domain_x_.size(),
00158               discrete_domain_x_.begin());
00159
00160     std::copy(grid.discrete_domain_y_.begin(),
00161               grid.discrete_domain_y_.begin() + grid.
    discrete_domain_y_.size(),
00162               discrete_domain_y_.begin());
00163
00164     std::copy(grid.discrete_field_.begin(),
00165               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00166               discrete_field_.begin());
00167 }
00168
00169 mtk::UniStgGrid2D::UniStgGrid2D(const Real &west_bndy,
00170                                 const Real &east_bndy,
00171                                 const int &num_cells_x,
00172                                 const Real &south_bndy,
00173                                 const Real &north_bndy,
00174                                 const int &num_cells_y,
00175                                 const mtk::FieldNature &nature) {
00176
00177   #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 mtk::Real mtk::UniStgGrid2D::south_bndy() const {
00231
00232   return south_bndy_;
00233 }
00234
00235 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00236
```

```
00237   return north_bndy_;
00238 }
00239
00240 int mtk::UniStgGrid2D::num_cells_y() const {
00241
00242   return num_cells_y_;
00243 }
00244
00245 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00246
00247   return delta_y_;
00248 }
00249
00250 void mtk::UniStgGrid2D::BindScalarField(Real (*ScalarField)(
      Real xx, Real yy)) {
00251
00252   #if MTK_DEBUG_LEVEL > 0
00253   mtk::Tools::Prevent(nature_ != mtk::SCALAR, __FILE__, __LINE__, __func__);
00254   #endif
00255
00257
00258   discrete_domain_x_.reserve(num_cells_x_ + 2);
00259
00260   discrete_domain_x_.push_back(west_bndy_);
00261   #ifdef MTK_PRECISION_DOUBLE
00262   auto first_center = west_bndy_ + delta_x_/2.0;
00263   #else
00264   auto first_center = west_bndy_ + delta_x_/2.0f;
00265   #endif
00266   discrete_domain_x_.push_back(first_center);
00267   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00268     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00269   }
00270   discrete_domain_x_.push_back(east_bndy_);
00271
00273
00274   discrete_domain_y_.reserve(num_cells_y_ + 2);
00275
00276   discrete_domain_y_.push_back(south_bndy_);
00277   #ifdef MTK_PRECISION_DOUBLE
00278   first_center = south_bndy_ + delta_x_/2.0;
00279   #else
00280   first_center = south_bndy_ + delta_x_/2.0f;
00281   #endif
00282   discrete_domain_y_.push_back(first_center);
00283   for (auto ii = 1; ii < num_cells_y_; ++ii) {
00284     discrete_domain_y_.push_back(first_center + ii*delta_y_);
00285   }
00286   discrete_domain_y_.push_back(north_bndy_);
00287
00289
00290   discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));
00291
00292   for (int ii = 0; ii < num_cells_x_ + 2; ++ii) {
00293     for (int jj = 0; jj < num_cells_y_ + 2; ++jj) {
00294       discrete_field_.push_back(ScalarField(discrete_domain_x_[ii],
00295                                             discrete_domain_y_[jj]));
00296     }
00297   }
00298 }
00299
00300 void mtk::UniStgGrid2D::BindVectorFieldPComponent(
00301   mtk::Real (*VectorField)(mtk::Real xx, mtk::Real yy)) {
00302
00303   int mm{num_cells_x_};
00304   int nn{num_cells_y_};
00305
00306   int total{nn*(mm + 1) + mm*(nn + 1)};
00307
00308   #ifdef MTK_PRECISION_DOUBLE
00309   double half_delta_x{delta_x_/2.0};
00310   double half_delta_y{delta_y_/2.0};
00311   #else
00312   float half_delta_x{delta_x_/2.0f};
00313   float half_delta_y{delta_y_/2.0f};
00314   #endif
00315
00317
00318   // We need every data point of the discrete domain; i.e. we need all the
00319   // nodes and all the centers. There are mm centers for the x direction, and
00320   // nn centers for the y direction. Since there is one node per center, that
```

```
00321   // amounts to 2*mm. If we finally consider the final boundary node, it
00322   // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00323   // y direction, this amounts to 2*nn + 1.
00324
00325   discrete_domain_x_.reserve(2*mm + 1);
00326
00327   discrete_domain_x_.push_back(west_bndy_);
00328   for (int ii = 1; ii < (2*mm + 1); ++ii) {
00329     discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00330   }
00331
00333
00334   discrete_domain_y_.reserve(2*nn + 1);
00335
00336   discrete_domain_y_.push_back(south_bndy_);
00337   for (int ii = 1; ii < (2*nn + 1); ++ii) {
00338     discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00339   }
00340
00342
00343   discrete_field_.reserve(total);
00344
00345   // For each y-center.
00346   for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00347
00348     // Bind all of the x-nodes for this y-center.
00349     for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00350       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00351                                             discrete_domain_y_[ii]));
00352
00353       #if MTK_DEBUG_LEVEL > 0
00354       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00355         discrete_domain_y_[ii] << " = " <<
00356         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00357       #endif
00358     }
00359   }
00360   #if MTK_DEBUG_LEVEL > 0
00361   std::cout << std::endl;
00362   #endif
00363 }
00364
00365 void mtk::UniStgGrid2D::BindVectorFieldQComponent(
00366   mtk::Real (*VectorField)(mtk::Real xx, mtk::Real yy)) {
00367
00368   int mm{num_cells_x_};
00369   int nn{num_cells_y_};
00370
00372
00373   // For each y-node.
00374   for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00375
00376     // Bind all of the x-center for this y-node.
00377     for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00378       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00379                                             discrete_domain_y_[ii]));
00380
00381       #if MTK_DEBUG_LEVEL > 0
00382       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00383         discrete_domain_y_[ii] << " = " <<
00384         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00385       #endif
00386     }
00387   }
00388   #if MTK_DEBUG_LEVEL > 0
00389   std::cout << std::endl;
00390   #endif
00391 }
00392
00393 void mtk::UniStgGrid2D::BindVectorField(
00394   Real (*VectorFieldPComponent)(Real xx,Real yy),
00395   Real (*VectorFieldQComponent)(Real xx,Real yy)) {
00396
00397   #if MTK_DEBUG_LEVEL > 0
00398   mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00399   #endif
00400
00401   BindVectorFieldPComponent(VectorFieldPComponent);
00402   BindVectorFieldQComponent(VectorFieldQComponent);
00403 }
00404
```

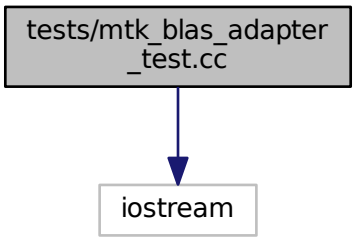
```
00405 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00406                                       std::string space_name_x,
00407                                       std::string space_name_y,
00408                                       std::string field_name) {
00409
00410   std::ofstream output_dat_file;  // Output file.
00411
00412   output_dat_file.open(filename);
00413
00414   if (!output_dat_file.is_open()) {
00415     return false;
00416   }
00417
00418   if (nature_ == mtk::SCALAR) {
00419     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00420       field_name << std::endl;
00421
00422     for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00423       for (unsigned int jj = 0; jj < discrete_domain_y_.size(); ++jj) {
00424         output_dat_file << discrete_domain_x_[ii] << ' ' <<
00425                            discrete_domain_y_[jj] << ' ' <<
00426                            discrete_field_[ii*discrete_domain_y_.size() + jj] <<
00427                           std::endl;
00428       }
00429       output_dat_file << std::endl;
00430     }
00431   } else {
00432     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00433       field_name << std::endl;
00434
00435     output_dat_file << "# Horizontal component:" << std::endl;
00436
00437     int mm{num_cells_x_};
00438     int nn{num_cells_y_};
00439
00441
00442     // For each y-center.
00443     int idx{};
00444     for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00445       // Bind all of the x-nodes for this y-center.
00446       for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00447
00448         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00449           discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<
00450           mtk::kZero << std::endl;
00451
00452         ++idx;
00453       }
00454     }
00455
00457     int p_offset{nn*(mm + 1) - 1};
00458     idx = 0;
00459     output_dat_file << "# Vertical component:" << std::endl;
00460     // For each y-node.
00461     for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00462       // Bind all of the x-center for this y-node.
00463       for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00464
00465         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00466           discrete_domain_y_[ii] << ' ' << mtk::kZero << ' ' <<
00467           discrete_field_[p_offset + idx] << std::endl;
00468
00469         ++idx;
00470       }
00471     }
00472   }
00473
00474   output_dat_file.close();
00475
00476   return true;
00477 }
```

## 17.87 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 ()

### 17.87.1 Detailed Description

**Author**

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

Definition in file mtk_blas_adapter_test.cc.

### 17.87.2 Function Documentation

#### 17.87.2.1 int main ( )

Definition at line 109 of file mtk_blas_adapter_test.cc.

## 17.88 mtk_blas_adapter_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

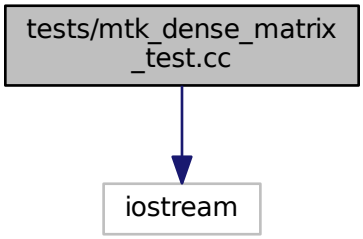
```
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <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
```

## 17.89 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 ()

### 17.89.1 Detailed Description

**Author**

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

Definition in file mtk_dense_matrix_test.cc.

### 17.89.2 Function Documentation

#### 17.89.2.1 int main ( )

Definition at line 330 of file mtk_dense_matrix_test.cc.

## 17.90 mtk_dense_matrix_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <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);
```

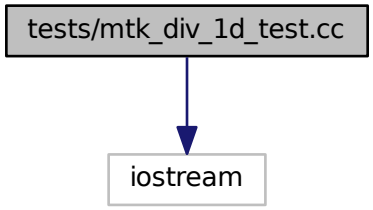
```
00247   rr.SetValue(2,9,5.0);
00248
00249   rr.SetValue(3,0,0.0);
00250   rr.SetValue(3,1,0.0);
00251   rr.SetValue(3,2,0.0);
00252   rr.SetValue(3,3,0.0);
00253   rr.SetValue(3,4,0.0);
00254   rr.SetValue(3,5,6.0);
00255   rr.SetValue(3,6,7.0);
00256   rr.SetValue(3,7,8.0);
00257   rr.SetValue(3,8,9.0);
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
```

## 17.91 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 ()

### 17.91.1 Detailed Description

**Author**

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

Definition in file mtk_div_1d_test.cc.

### 17.91.2 Function Documentation

#### 17.91.2.1 int main ( )

Definition at line 288 of file mtk_div_1d_test.cc.

## 17.92 mtk_div_1d_test.cc

```
00001
```

```
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Div1D div2;
00065
00066   bool assertion = div2.ConstructDiv1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00070   }
00071
00072   mtk::Tools::EndUnitTestNo(1);
00073   mtk::Tools::Assert(assertion);
00074 }
00075
00076 void TestDefaultConstructorFactoryMethodFourthOrder() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Div1D div4;
00081
00082   bool assertion = div4.ConstructDiv1D(4);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(2);
```

```
00089   mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestDefaultConstructorFactoryMethodSixthOrder() {
00093
00094   mtk::Tools::BeginUnitTestNo(3);
00095
00096   mtk::Div1D div6;
00097
00098   bool assertion = div6.ConstructDiv1D(6);
00099
00100   if (!assertion) {
00101     std::cerr << "Mimetic div (6th order) could not be built." << std::endl;
00102   }
00103
00104   mtk::Tools::EndUnitTestNo(3);
00105   mtk::Tools::Assert(assertion);
00106 }
00107
00108 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00109
00110   mtk::Tools::BeginUnitTestNo(4);
00111
00112   mtk::Div1D div8;
00113
00114   bool assertion = div8.ConstructDiv1D(8);
00115
00116   if (!assertion) {
00117     std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00118   }
00119
00120   mtk::Tools::EndUnitTestNo(4);
00121   mtk::Tools::Assert(assertion);
00122 }
00123
00124 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00125
00126   mtk::Tools::BeginUnitTestNo(5);
00127
00128   mtk::Div1D div10;
00129
00130   bool assertion = div10.ConstructDiv1D(10);
00131
00132   if (!assertion) {
00133     std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00134   }
00135
00136   mtk::Tools::EndUnitTestNo(5);
00137   mtk::Tools::Assert(assertion);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142   mtk::Tools::BeginUnitTestNo(6);
00143
00144   mtk::Div1D div12;
00145
00146   bool assertion = div12.ConstructDiv1D(12);
00147
00148   if (!assertion) {
00149     std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00150   }
00151
00152   mtk::Tools::EndUnitTestNo(6);
00153   mtk::Tools::Assert(assertion);
00154 }
00155
00156 void TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold() {
00157
00158   mtk::Tools::BeginUnitTestNo(7);
00159
00160   mtk::Div1D div14;
00161
00162   bool assertion = div14.ConstructDiv1D(14);
00163
00164   if (!assertion) {
00165     std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00166   }
00167
00168   mtk::Tools::EndUnitTestNo(7);
00169   mtk::Tools::Assert(assertion);
```

```
00170 }
00171
00172 void TestSecondOrderReturnAsDenseMatrixWithGrid() {
00173
00174   mtk::Tools::BeginUnitTestNo(8);
00175
00176   mtk::Div1D div2;
00177
00178   bool assertion = div2.ConstructDiv1D();
00179
00180   if (!assertion) {
00181     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00182   }
00183
00184   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00185
00186   mtk::DenseMatrix div2m(div2.ReturnAsDenseMatrix(grid));
00187
00188   int rr{7};
00189   int cc{6};
00190
00191   mtk::DenseMatrix ref(rr, cc);
00192
00193   // Row 2.
00194   ref.SetValue(1,0,-5.0);
00195   ref.SetValue(1,1,5.0);
00196   ref.SetValue(1,2,0.0);
00197   ref.SetValue(1,3,0.0);
00198   ref.SetValue(1,4,0.0);
00199   ref.SetValue(1,5,0.0);
00200   ref.SetValue(1,6,0.0);
00201
00202   // Row 3.
00203   ref.SetValue(2,0,0.0);
00204   ref.SetValue(2,1,-5.0);
00205   ref.SetValue(2,2,5.0);
00206   ref.SetValue(2,3,0.0);
00207   ref.SetValue(2,4,0.0);
00208   ref.SetValue(2,5,0.0);
00209   ref.SetValue(2,6,0.0);
00210
00211   // Row 4.
00212   ref.SetValue(3,0,0.0);
00213   ref.SetValue(3,1,0.0);
00214   ref.SetValue(3,2,-5.0);
00215   ref.SetValue(3,3,5.0);
00216   ref.SetValue(3,4,0.0);
00217   ref.SetValue(3,5,0.0);
00218   ref.SetValue(3,6,0.0);
00219
00220   // Row 5.
00221   ref.SetValue(4,0,0.0);
00222   ref.SetValue(4,1,0.0);
00223   ref.SetValue(4,2,0.0);
00224   ref.SetValue(4,3,-5.0);
00225   ref.SetValue(4,4,5.0);
00226   ref.SetValue(4,5,0.0);
00227   ref.SetValue(4,6,0.0);
00228
00229   // Row 6.
00230   ref.SetValue(5,0,0.0);
00231   ref.SetValue(5,1,0.0);
00232   ref.SetValue(5,2,0.0);
00233   ref.SetValue(5,3,0.0);
00234   ref.SetValue(5,4,-5.0);
00235   ref.SetValue(5,5,5.0);
00236   ref.SetValue(5,6,0.0);
00237
00238   assertion = assertion && (div2m == ref);
00239
00240   mtk::Tools::EndUnitTestNo(8);
00241   mtk::Tools::Assert(assertion);
00242 }
00243
00244 void TestFourthOrderReturnAsDenseMatrixWithGrid() {
00245
00246   mtk::Tools::BeginUnitTestNo(9);
00247
00248   mtk::Div1D div4;
00249
00250   bool assertion = div4.ConstructDiv1D(4);
```

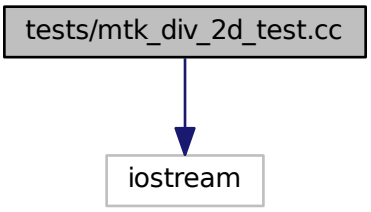
```
00251
00252   if (!assertion) {
00253     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00254   }
00255
00256   std::cout << div4 << std::endl;
00257
00258   mtk::UniStgGrid1D grid(0.0, 1.0, 11);
00259
00260   std::cout << grid << std::endl;
00261
00262   mtk::DenseMatrix div4m(div4.ReturnAsDenseMatrix(grid));
00263
00264   std::cout << div4m << std::endl;
00265
00266   mtk::Tools::EndUnitTestNo(9);
00267 }
00268
00269 int main () {
00270
00271   std::cout << "Testing mtk::Div1D class." << std::endl;
00272
00273   TestDefaultConstructorFactoryMethodDefault();
00274   TestDefaultConstructorFactoryMethodFourthOrder();
00275   TestDefaultConstructorFactoryMethodSixthOrder();
00276   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00277   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00278   TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00279   TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold();
00280   TestSecondOrderReturnAsDenseMatrixWithGrid();
00281   TestFourthOrderReturnAsDenseMatrixWithGrid();
00282 }
00283
00284 #else
00285 #include <iostream>
00286 using std::cout;
00287 using std::endl;
00288 int main () {
00289   cout << "This code HAS to be compiled with support for C++11." << endl;
00290   cout << "Exiting..." << endl;
00291 }
00292 #endif
```

## 17.93 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 ()

### 17.93.1 Detailed Description

**Author**

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

Definition in file mtk_div_2d_test.cc.

### 17.93.2 Function Documentation

#### 17.93.2.1 int main ( )

Definition at line 139 of file mtk_div_2d_test.cc.

## 17.94 mtk_div_2d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

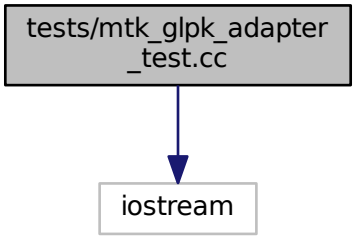
```
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Div2D dd;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real ee = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00078
00079   bool assertion = dd.ConstructDiv2D(ddg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Div2D dd;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real ee = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00104
00105   bool assertion = dd.ConstructDiv2D(ddg);
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (ddm.num_rows() != mtk::kZero);
00114
00115   std::cout << ddm << std::endl;
00116
00117   assertion = assertion && ddm.WriteToFile("mtk_div_2d_test_02.dat");
00118
00119   if(!assertion) {
00120     std::cerr << "Error writing to file." << std::endl;
00121   }
00122
00123   mtk::Tools::EndUnitTestNo(2);
00124   mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129   std::cout << "Testing mtk::Div2D class." << std::endl;
00130
00131   TestDefaultConstructorFactory();
00132   TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
```

```
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140   cout << "This code HAS to be compiled with support for C++11." << endl;
00141   cout << "Exiting..." << endl;
00142 }
00143 #endif
```

## 17.95 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 ()

### 17.95.1 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.

### 17.95.2 Function Documentation

#### 17.95.2.1 int main ( )

Definition at line 81 of file mtk_glpk_adapter_test.cc.

## 17.96 mtk_glpk_adapter_test.cc

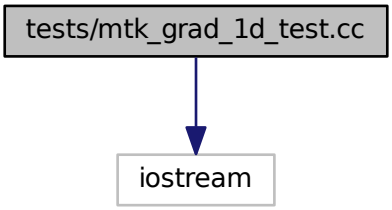
```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #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
```

## 17.97 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 ()

### 17.97.1 Detailed Description

**Author**

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

Definition in file mtk_grad_1d_test.cc.

### 17.97.2 Function Documentation

#### 17.97.2.1 int main ( )

Definition at line 296 of file mtk_grad_1d_test.cc.

## 17.98 mtk_grad_1d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
```

```
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Grad1D grad2;
00065
00066   bool assertion = grad2.ConstructGrad1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00070
00071   }
00072
00073   std::cout << grad2 << std::endl;
00074
00075   mtk::Tools::EndUnitTestNo(1);
00076   mtk::Tools::Assert(assertion);
00077 }
00078
00079 void TestDefaultConstructorFactoryMethodFourthOrder() {
00080
00081   mtk::Tools::BeginUnitTestNo(2);
00082
00083   mtk::Grad1D grad4;
00084
00085   bool assertion = grad4.ConstructGrad1D(4);
00086
00087   if (!assertion) {
00088     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00089   }
00090
00091   std::cout << grad4 << std::endl;
00092
00093   mtk::Tools::EndUnitTestNo(2);
00094   mtk::Tools::Assert(assertion);
00095 }
00096
00097 void TestDefaultConstructorFactoryMethodSixthOrder() {
00098
00099   mtk::Tools::BeginUnitTestNo(3);
```

```
00100
00101   mtk::Grad1D grad6;
00102
00103   bool assertion = grad6.ConstructGrad1D(6);
00104
00105   if (!assertion) {
00106     std::cerr << "Mimetic grad (6th order) could not be built." << std::endl;
00107   }
00108
00109   std::cout << grad6 << std::endl;
00110
00111   mtk::Tools::EndUnitTestNo(3);
00112   mtk::Tools::Assert(assertion);
00113 }
00114
00115 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00116
00117   mtk::Tools::BeginUnitTestNo(4);
00118
00119   mtk::Grad1D grad8;
00120
00121   bool assertion = grad8.ConstructGrad1D(8);
00122
00123   if (!assertion) {
00124     std::cerr << "Mimetic grad (8th order) could not be built." << std::endl;
00125   }
00126
00127   std::cout << grad8 << std::endl;
00128
00129   mtk::Tools::EndUnitTestNo(4);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00134
00135   mtk::Tools::BeginUnitTestNo(5);
00136
00137   mtk::Grad1D grad10;
00138
00139   bool assertion = grad10.ConstructGrad1D(10);
00140
00141   if (!assertion) {
00142     std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00143   }
00144
00145   std::cout << grad10 << std::endl;
00146
00147   mtk::Tools::EndUnitTestNo(5);
00148   mtk::Tools::Assert(assertion);
00149 }
00150
00151 void TestReturnAsDenseMatrixWithGrid() {
00152
00153   mtk::Tools::BeginUnitTestNo(6);
00154
00155   mtk::Grad1D grad2;
00156
00157   bool assertion = grad2.ConstructGrad1D();
00158
00159   if (!assertion) {
00160     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00161   }
00162
00163   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00164
00165   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00166
00167   int rr{6};
00168   int cc{7};
00169
00170   mtk::DenseMatrix ref(rr, cc);
00171
00172   // Row 1.
00173   ref.SetValue(0,0,-13.3333);
00174   ref.SetValue(0,1,15);
00175   ref.SetValue(0,2,-1.66667);
00176   ref.SetValue(0,3,0.0);
00177   ref.SetValue(0,4,0.0);
00178   ref.SetValue(0,5,0.0);
00179   ref.SetValue(0,6,0.0);
00180
```

```
00181   // Row 2.
00182   ref.SetValue(1,0,0.0);
00183   ref.SetValue(1,1,-5.0);
00184   ref.SetValue(1,2,5.0);
00185   ref.SetValue(1,3,0.0);
00186   ref.SetValue(1,4,0.0);
00187   ref.SetValue(1,5,0.0);
00188   ref.SetValue(1,6,0.0);
00189
00190   // Row 3.
00191   ref.SetValue(2,0,0.0);
00192   ref.SetValue(2,1,0.0);
00193   ref.SetValue(2,2,-5.0);
00194   ref.SetValue(2,3,5.0);
00195   ref.SetValue(2,4,0.0);
00196   ref.SetValue(2,5,0.0);
00197   ref.SetValue(2,6,0.0);
00198
00199   // Row 4.
00200   ref.SetValue(3,0,0.0);
00201   ref.SetValue(3,1,0.0);
00202   ref.SetValue(3,2,0.0);
00203   ref.SetValue(3,3,-5.0);
00204   ref.SetValue(3,4,5.0);
00205   ref.SetValue(3,5,0.0);
00206   ref.SetValue(3,6,0.0);
00207
00208   // Row 5.
00209   ref.SetValue(4,0,0.0);
00210   ref.SetValue(4,1,0.0);
00211   ref.SetValue(4,2,0.0);
00212   ref.SetValue(4,3,0.0);
00213   ref.SetValue(4,4,-5.0);
00214   ref.SetValue(4,5,5.0);
00215   ref.SetValue(4,6,0.0);
00216
00217   // Row 6.
00218   ref.SetValue(5,0,0.0);
00219   ref.SetValue(5,1,0.0);
00220   ref.SetValue(5,2,0.0);
00221   ref.SetValue(5,3,0.0);
00222   ref.SetValue(5,4,1.66667);
00223   ref.SetValue(5,5,-15.0);
00224   ref.SetValue(5,6,13.3333);
00225
00226   mtk::Tools::EndUnitTestNo(6);
00227   mtk::Tools::Assert(grad2m == ref);
00228 }
00229
00230 void TestReturnAsDimensionlessDenseMatrix() {
00231
00232   mtk::Tools::BeginUnitTestNo(7);
00233
00234   mtk::Grad1D grad4;
00235
00236   bool assertion = grad4.ConstructGrad1D(4);
00237
00238   if (!assertion) {
00239     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00240   }
00241
00242   mtk::DenseMatrix grad4m(grad4.ReturnAsDimensionlessDenseMatrix
      (10));
00243
00244   std::cout << grad4m << std::endl;
00245
00246   mtk::Tools::EndUnitTestNo(7);
00247   mtk::Tools::Assert(assertion);
00248 }
00249
00250 void TestWriteToFile() {
00251
00252   mtk::Tools::BeginUnitTestNo(8);
00253
00254   mtk::Grad1D grad2;
00255
00256   bool assertion = grad2.ConstructGrad1D();
00257
00258   if (!assertion) {
00259     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00260   }
```

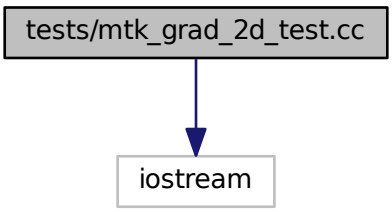
```
00261
00262   mtk::UniStgGrid1D grid(0.0, 1.0, 50);
00263
00264   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00265
00266   std::cout << grad2m << std::endl;
00267
00268   assertion = assertion && grad2m.WriteToFile("mtk_grad_1d_test_08.dat");
00269
00270   if(!assertion) {
00271     std::cerr << "Error writing to file." << std::endl;
00272   }
00273
00274   mtk::Tools::EndUnitTestNo(8);
00275   mtk::Tools::Assert(assertion);
00276 }
00277
00278 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
```

## 17.99 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 ()

### 17.99.1 Detailed Description

**Author**

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

Definition in file mtk_grad_2d_test.cc.

### 17.99.2 Function Documentation

#### 17.99.2.1 int main ( )

Definition at line 139 of file mtk_grad_2d_test.cc.

## 17.100 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:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

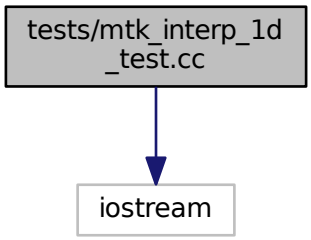
```
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Grad2D gg;
00068
00069   mtk::Real 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
```

## 17.101 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 ()

### 17.101.1 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.

### 17.101.2 Function Documentation

#### 17.101.2.1 int main ( )

Definition at line 113 of file mtk_interp_1d_test.cc.

# 17.102 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
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #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) {
```

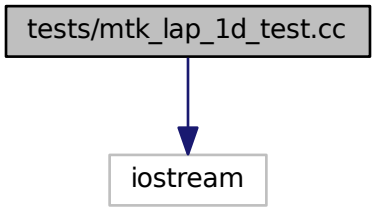
```
00087     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00088   }
00089
00090   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00091
00092   mtk::DenseMatrix interpm(inter.ReturnAsDenseMatrix(grid));
00093
00094   assertion =
00095     assertion && interpm.GetValue(0,0) == 1.0 && 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
```

## 17.103 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 ()

### 17.103.1 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_lap_1d_test.cc.

### 17.103.2 Function Documentation

#### 17.103.2.1 int main ( )

Definition at line 193 of file mtk_lap_1d_test.cc.

## 17.104 mtk_lap_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
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #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
```

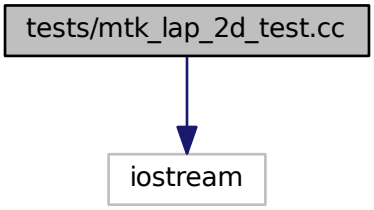
```
00146   bool assertion = lap12.ConstructLap1D(12);
00147
00148   if (!assertion) {
00149     std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00150   }
00151
00152   mtk::Tools::EndUnitTestNo(6);
00153 }
00154
00155 void TestReturnAsDenseMatrix() {
00156
00157   mtk::Tools::BeginUnitTestNo(8);
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
```

## 17.105 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 ()

### 17.105.1 Detailed Description

**Author**

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

Definition in file mtk_lap_2d_test.cc.

### 17.105.2 Function Documentation

#### 17.105.2.1 int main ( )

Definition at line 139 of file mtk_lap_2d_test.cc.

## 17.106 mtk_lap_2d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
```

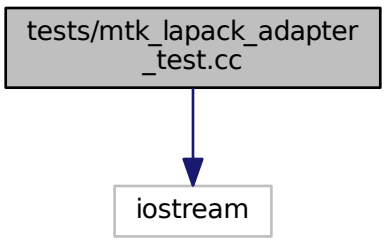
```
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Lap2D ll;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00078
00079   bool assertion = ll.ConstructLap2D(llg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Lap2D ll;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real dd = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00104
00105   bool assertion = ll.ConstructLap2D(llg);
```

```
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (llm.num_rows() != mtk::kZero);
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
```

## 17.107 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 ()

### 17.107.1 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.

### 17.107.2 Function Documentation

#### 17.107.2.1 int main ( )

Definition at line 81 of file mtk_lapack_adapter_test.cc.

## 17.108 mtk_lapack_adapter_test.cc

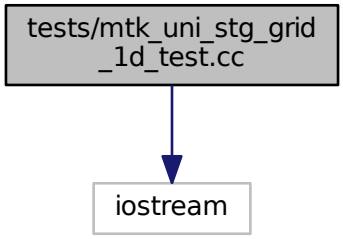
```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
00026 3. Redistributions in binary form must reproduce the above copyright notice,
00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
00029
00030 4. Usage of the binary form on proprietary applications shall require explicit
00031 prior written permission from the the copyright holders, and due credit should
00032 be given to the copyright holders.
00033
00034 5. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
```

```
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072   std::cout << "Testing mtk::LAPACKAdapter class." << std::endl;
00073
00074   Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082   cout << "This code HAS to be compiled with support for C++11." << endl;
00083   cout << "Exiting..." << endl;
00084 }
00085 #endif
```

## 17.109 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 ()

### 17.109.1 Detailed Description

**Author**

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

Definition in file mtk_uni_stg_grid_1d_test.cc.

### 17.109.2 Function Documentation

#### 17.109.2.1 int main ( )

Definition at line 172 of file mtk_uni_stg_grid_1d_test.cc.

## 17.110 mtk_uni_stg_grid_1d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <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;
```

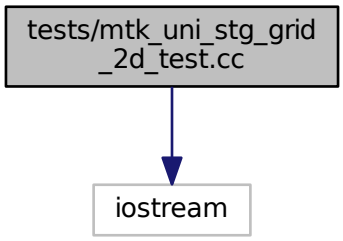
```
00074 }
00075
00076 void TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Real aa = 0.0;
00081   mtk::Real bb = 1.0;
00082
00083   int nn = 5;
00084
00085   mtk::UniStgGrid1D gg(aa, bb, nn);
00086
00087   gg.BindScalarField(ScalarField);
00088
00089   std::cout << gg << std::endl;
00090
00091   mtk::Tools::EndUnitTestNo(2);
00092   mtk::Tools::Assert(gg.delta_x() == 0.2 && gg.
      num_cells_x() == 5);
00093 }
00094
00095 void TestBindScalarFieldWriteToFile() {
00096
00097   mtk::Tools::BeginUnitTestNo(3);
00098
00099   mtk::Real aa = 0.0;
00100   mtk::Real bb = 1.0;
00101
00102   int nn = 5;
00103
00104   mtk::UniStgGrid1D gg(aa, bb, nn);
00105
00106   bool assertion{true};
00107
00108   gg.BindScalarField(ScalarField);
00109
00110   assertion =
00111     assertion &&
00112     gg.discrete_field_u()[0] == 0.0 &&
00113     gg.discrete_field_u()[gg.num_cells_x() + 2 - 1] == 2.0;
00114
00115   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_03.dat", "x", "u(x)")) {
00116     std::cerr << "Error writing to file." << std::endl;
00117     assertion = false;
00118   }
00119
00120   mtk::Tools::EndUnitTestNo(3);
00121   mtk::Tools::Assert(assertion);
00122 }
00123
00124 mtk::Real VectorFieldPComponent(mtk::Real xx) {
00125
00126   return xx*xx;
00127 }
00128
00129 void TestBindVectorField() {
00130
00131   mtk::Tools::BeginUnitTestNo(4);
00132
00133   mtk::Real aa = 0.0;
00134   mtk::Real bb = 1.0;
00135
00136   int nn = 20;
00137
00138   mtk::UniStgGrid1D gg(aa, bb, nn, mtk::VECTOR);
00139
00140   bool assertion{true};
00141
00142   gg.BindVectorField(VectorFieldPComponent);
00143
00144   assertion =
00145     assertion &&
00146     gg.discrete_field_u()[0] == 0.0 &&
00147     gg.discrete_field_u()[gg.num_cells_x() + 1 - 1] == 1.0;
00148
00149   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_04.dat", "x", "v(x)")) {
00150     std::cerr << "Error writing to file." << std::endl;
00151     assertion = false;
00152   }
00153
```

```
00154   mtk::Tools::EndUnitTestNo(4);
00155   mtk::Tools::Assert(assertion);
00156 }
00157
00158 int main () {
00159
00160   std::cout << "Testing mtk::UniStgGrid1D class." << std::endl;
00161
00162   TestDefaultConstructor();
00163   TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField();
00164   TestBindScalarFieldWriteToFile();
00165   TestBindVectorField();
00166 }
00167
00168 #else
00169 #include <iostream>
00170 using std::cout;
00171 using std::endl;
00172 int main () {
00173   cout << "This code HAS to be compiled with support for C++11." << endl;
00174   cout << "Exiting..." << endl;
00175 }
00176 #endif
```

## 17.111 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 ()

### 17.111.1 Detailed Description

**Author**

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

Definition in file mtk_uni_stg_grid_2d_test.cc.

### 17.111.2 Function Documentation

#### 17.111.2.1 int main ( )

Definition at line 202 of file mtk_uni_stg_grid_2d_test.cc.

## 17.112 mtk_uni_stg_grid_2d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
00032 5. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructor() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::UniStgGrid2D gg;
00068
00069   mtk::Tools::EndUnitTestNo(1);
00070   mtk::Tools::Assert(gg.delta_x() == mtk::kZero && gg.
      delta_y() == mtk::kZero);
00071 }
00072
```

```
00073 void
00074 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator() {
00075
00076   mtk::Tools::BeginUnitTestNo(2);
00077
00078   mtk::Real aa = 0.0;
00079   mtk::Real bb = 1.0;
00080   mtk::Real cc = 0.0;
00081   mtk::Real dd = 1.0;
00082
00083   int nn = 5;
00084   int mm = 7;
00085
00086   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00087
00088   std::cout << gg << std::endl;
00089
00090   mtk::Tools::EndUnitTestNo(2);
00091   mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00092                      abs(gg.delta_y() - 0.142857) <
      mtk::kDefaultTolerance);
00093 }
00094
00095 void TestGetters() {
00096
00097   mtk::Tools::BeginUnitTestNo(3);
00098
00099   mtk::Real aa = 0.0;
00100   mtk::Real bb = 1.0;
00101   mtk::Real cc = 0.0;
00102   mtk::Real dd = 1.0;
00103
00104   int nn = 5;
00105   int mm = 7;
00106
00107   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00108
00109   bool assertion{true};
00110
00111   assertion = assertion && (gg.west_bndy() == aa);
00112   assertion = assertion && (gg.east_bndy() == bb);
00113   assertion = assertion && (gg.num_cells_x() == nn);
00114   assertion = assertion && (gg.south_bndy() == cc);
00115   assertion = assertion && (gg.north_bndy() == dd);
00116   assertion = assertion && (gg.num_cells_y() == mm);
00117
00118   mtk::Tools::EndUnitTestNo(3);
00119   mtk::Tools::Assert(assertion);
00120 }
00121
00122 mtk::Real ScalarField(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
```

# Index