MTK: Mimetic Methods Toolkit

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Contents

Chapter 1

Introduction

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

The **Mimetic Methods Toolkit (MTK)** is a C++11 library for mimetic numerical methods. It is a set of classes for **mimetic interpolation**, **mimetic quadratures**, and **mimetic finite difference** methods for the **numerical solution of ordinary and partial differential equations**.

1.1 MTK Concerns

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

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

In order of dependence these are:

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

1.2 MTK Wrappers

The MTK collection of wrappers is:

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

Others are being strongly considered.

1.3 Contact, Support and Credits

The GitHub repository is: https://github.com/ejspeiro/MTK

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

Currently the developers are:

- **Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu** - ejspeiro
- Jose E. Castillo, PhD - jcastillo at mail dot sdsu dot edu
- Guillermo F. Miranda, PhD - unigrav at hotmail dot com
- Christopher P. Paolini, PhD - paolini at engineering dot sdsu dot edu
- Angel Boada.
- Johnny Corbino.
- Raul Vargas-Navarro.

1.3.1 Acknowledgements and Contributions

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

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

Chapter 2

Referencing This Work

Please reference this work as follows:

```
@article{Sanchez2014308,
  title = "The Mimetic Methods Toolkit: An object-oriented \{API\} for Mimetic
Finite Differences ",
  journal = "Journal of Computational and Applied Mathematics ",
  volume = "270",
  number = "",
  pages = "308 - 322",
  year = "2014",
  note = "Fourth International Conference on Finite Element Methods in
Engineering and Sciences (FEMTEC 2013) ",
  issn = "0377-0427",
  doi = "http://dx.doi.org/10.1016/j.cam.2013.12.046",
  url = "http://www.sciencedirect.com/science/article/pii/S037704271300719X",
  author = "Eduardo J. Sanchez and Christopher P. Paolini and Jose E. Castillo",
  keywords = "Object-oriented development",
  keywords = "Partial differential equations",
  keywords = "Application programming interfaces",
  keywords = "Mimetic Finite Differences "
}

@Inbook{Sanchez2015,
  author="Sanchez, Eduardo and Paolini, Christopher and Blomgren, Peter
and Castillo, Jose",
  editor="Kirby, M. Robert and Berzins, Martin and Hesthaven, S. Jan",
  chapter="Algorithms for Higher-Order Mimetic Operators",
  title="Spectral and High Order Methods for Partial Differential Equations
ICOSAHOM 2014: Selected papers from the ICOSAHOM conference, June 23-27, 2014,
Salt Lake City, Utah, USA",
  year="2015",
  publisher="Springer International Publishing",
  address="Cham",
  pages="425--434",
  isbn="978-3-319-19800-2",
  doi="10.1007/978-3-319-19800-2_39",
  url="http://dx.doi.org/10.1007/978-3-319-19800-2_39"
}
```

Chapter 3

Read Me File and Installation Instructions

```
# The Mimetic Methods Toolkit (MTK)

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

## 1. Description

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

The **Mimetic Methods Toolkit (MTK)** is a C++11 library for mimetic numerical
methods. It is a set of classes for **mimetic interpolation**, **mimetic
quadratures**, and **mimetic finite difference** methods for the **numerical
solution of ordinary and partial differential equations**.

## 2. Dependencies

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

```
$(HOME)/Libraries/
```

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

For Linux:

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

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

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

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

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

For OS X:

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

3. Installation
```

```
### PART 1. CONFIGURATION OF THE MAKEFILE.

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

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

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

- testall: runs all the tests.

- gendoc: generates the documentation for the library.

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

### PART 2. BUILD THE LIBRARY.

'''
$ make
'''

If successful you'll read (before building the tests and examples):
'''
----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
'''

## 4. Contact, Support, and Credits

The GitHub repository is: https://github.com/ejspeiro/MTK

The MTK is developed by researchers and adjuncts to the
[Computational Science Research Center (CSRC)](http://www.csrc.sdsu.edu/)
at [San Diego State University (SDSU)](http://www.sdsu.edu/).

Currently the developers are:

- **Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu** - @ejspeiro
- Jose E. Castillo, PhD - jcastillo at mail dot sdsu dot edu
- Guillermo F. Miranda, PhD - unigrav at hotmail dot com
- Christopher P. Paolini, PhD - paolini at engineering dot sdsu dot edu
- Angel Boada.
- Johnny Corbino.
- Raul Vargas-Navarro.

### 4.1. Acknowledgements and Contributions

The authors would like to acknowledge valuable advising, feedback,
and actual contributions from research personnel at the Computational Science
Research Center (CSRC) at San Diego State University (SDSU). Their input was
important to the fruition of this work. Specifically, our thanks go to
(alphabetical order):

- Mohammad Abouali, PhD
- Dany De Cecchis, PhD
```

- Otilio Rojas, PhD
- Julia Rossi.

5. Referencing This Work

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  year = "2014",
  note = "Fourth International Conference on Finite Element Methods in
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  issn = "0377-0427",
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  url = "http://www.sciencedirect.com/science/article/pii/S037704271300719X",
  author = "Eduardo J. Sanchez and Christopher P. Paolini and Jose E. Castillo",
  keywords = "Object-oriented development",
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  keywords = "Application programming interfaces",
  keywords = "Mimetic Finite Differences "
}

@Inbook{Sanchez2015,
  author="Sanchez, Eduardo and Paolini, Christopher and Blomgren, Peter
and Castillo, Jose",
  editor="Kirby, M. Robert and Berzins, Martin and Hesthaven, S. Jan",
  chapter="Algorithms for Higher-Order Mimetic Operators",
  title="Spectral and High Order Methods for Partial Differential Equations
ICOSAHOM 2014: Selected papers from the ICOSAHOM conference, June 23-27, 2014,
Salt Lake City, Utah, USA",
  year="2015",
  publisher="Springer International Publishing",
  address="Cham",
  pages="425--434",
  isbn="978-3-319-19800-2",
  doi="10.1007/978-3-319-19800-2_39",
  url="http://dx.doi.org/10.1007/978-3-319-19800-2_39"
}
```

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

Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu - @ejspeiro

Thanks and happy coding!

Chapter 4

Programming Tools

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

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

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

Chapter 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 tests and the examples:

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

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

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

Further architectures will be tested!

Chapter 6

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 7

Examples

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

Chapter 8

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.

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

Chapter 9

Todo List

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

Implement Kronecker product using the BLAS.

Implement Kron using the BLAS.

Member mtk::DenseMatrix::OrderColMajor ()

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

Member mtk::DenseMatrix::OrderRowMajor ()

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

Member mtk::DenseMatrix::Transpose ()

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

Class mtk::GLPKAdapter

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

Member mtk::Matrix::IncreaseNumNull () noexcept

Review the definition of sparse matrices properties.

Member mtk::Matrix::IncreaseNumZero () noexcept

Review the definition of sparse matrices properties.

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

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

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

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

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

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

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

Check if this is the best way of stalling execution.

Member mtk::UniStgGrid1D::discrete_domain_x () const

Review const-correctness of the pointer we return.

Member mtk::UniStgGrid1D::discrete_field ()

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

Member mtk::UniStgGrid2D::discrete_domain_x () const

Review const-correctness of the pointer we return.

Member mtk::UniStgGrid2D::discrete_domain_y () const

Review const-correctness of the pointer we return.

Member mtk::UniStgGrid3D::discrete_domain_x () const

Review const-correctness of the pointer we return.

Member mtk::UniStgGrid3D::discrete_domain_y () const

Review const-correctness of the pointer we return.

Member mtk::UniStgGrid3D::discrete_domain_z () const

Review const-correctness of the pointer we return.

File mtk_blas_adapter.cc

Write documentation using LaTeX.

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

Test selective precision mechanisms.

File mtk_uni_stg_grid_1d.h

Create overloaded binding routines that read data from files.

File mtk_uni_stg_grid_2d.h

Create overloaded binding routines that read data from files.

File mtk_uni_stg_grid_3d.h

Create overloaded binding routines that read data from files.

Chapter 10

Bug List

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

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

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

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

Chapter 11

Module Index

11.1 Modules

Here is a list of all modules:

Chapter 12

Namespace Index

12.1 Namespace List

Here is a list of all namespaces with brief descriptions:

Chapter 13

Class Index

13.1 Class List

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

Chapter 14

File Index

14.1 File List

Here is a list of all files with brief descriptions:

Chapter 15

Module Documentation

15.1 Roots.

Fundamental execution parameters and defined types.

Typedefs

- typedef float mtk::Real

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

Variables

- const float mtk::kZero {0.0f}

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

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

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

  Considered tolerance for comparisons in numerical methods.
- const float mtk::kDefaultMimeticThreshold {1e-6f}

  Default tolerance for higher-order mimetic operators.
- const int mtk::kDefaultOrderAccuracy {2}

  Default order of accuracy for mimetic operators.
- const int mtk::kCriticalOrderAccuracyGrad {10}

  At this order (and higher) we must use the CBSA to construct gradients.
- const int mtk::kCriticalOrderAccuracyDiv {8}

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

15.1.1 Detailed Description

Fundamental execution parameters and defined types.

15.1.2 Typedef Documentation

15.1.2.1 mtk::Real

Warning

Defined as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 93 of file mtk_roots.h.

15.1.3 Variable Documentation

15.1.3.1 mtk::kCriticalOrderAccuracyDiv {8}

Definition at line 186 of file mtk_roots.h.

15.1.3.2 mtk::kCriticalOrderAccuracyGrad {10}

Definition at line 177 of file mtk_roots.h.

15.1.3.3 mtk::kDefaultMimeticThreshold {1e-6f}

Warning

Declared as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 158 of file mtk_roots.h.

15.1.3.4 mtk::kDefaultOrderAccuracy {2}

Definition at line 168 of file mtk_roots.h.

15.1.3.5 mtk::kDefaultTolerance {1e-7f}

Warning

Declared as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 143 of file mtk_roots.h.

15.1.3.6 mtk::kOne {1.0f}

Warning

Declared as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 127 of file mtk_roots.h.

15.1.3.7 mtk::kTwo {2.0f}

Warning

Declared as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 128 of file mtk_roots.h.

15.1.3.8 mtk::kZero {0.0f}

Warning

Declared as double if MTK_PRECISION_DOUBLE is defined on Makefile.inc.

Definition at line 126 of file mtk_roots.h.

15.2 Enumerations.

Enumerations.

Enumerations

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

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

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

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

  Interpolation operator.

15.2.1 Detailed Description

Enumerations.

15.2.2 Enumeration Type Documentation

15.2.2.1 enum mtk::DirInterp [strong]

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.

15.2.2.2 enum mtk::FieldNature [strong]

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.

15.2.2.3 enum mtk::MatrixOrdering [strong]

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.

15.2.2.4 enum mtk::MatrixStorage [strong]

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.

15.3 Execution tools.

Tools to ensure execution correctness.

Classes

- class mtk::Tools

  Tool manager class.

15.3.1 Detailed Description

Tools to ensure execution correctness.

15.4 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.

15.4.1 Detailed Description

Fundamental data structures.

15.5 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.

15.5.1 Detailed Description

Adapter classes and auxiliary numerical methods.

15.6 Grids.

Uniform rectangular staggered grids.

Classes

- class mtk::UniStgGrid1D

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

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

  Uniform 3D Staggered Grid.

15.6.1 Detailed Description

Uniform rectangular staggered grids.

15.7 Mimetic operators.

Mimetic operators.

Classes

- class mtk::Curl2D

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

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

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

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

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

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

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

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

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

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

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

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

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

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

  Impose Robin boundary conditions on the operators and on the grids.
- class mtk::RobinBCDescriptor3D

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

Typedefs

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

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

  A function of a BC coefficient evaluated on a 1D domain and time.
- typedef Real(∗ mtk::CoefficientFunction2D)(const Real &xx, const Real &yy, const Real &tt)

  A function of a BC coefficient evaluated on a 2D domain and time.

15.7.1 Detailed Description

Mimetic operators.

15.7.2 Typedef Documentation

15.7.2.1 mtk::CoefficientFunction0D

Warning

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

Definition at line 111 of file mtk_robin_bc_descriptor_1d.h.

15.7.2.2 mtk::CoefficientFunction1D

Definition at line 97 of file mtk_robin_bc_descriptor_2d.h.

15.7.2.3 mtk::CoefficientFunction2D

Definition at line 97 of file mtk_robin_bc_descriptor_3d.h.

Chapter 16

Namespace Documentation

16.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

Classes

- class BLASAdapter

  Adapter class for the BLAS API.
- class Curl2D

  Implements a 2D mimetic curl operator.
- class DenseMatrix

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

  Implements a 1D mimetic divergence operator.
- class Div2D

  Implements a 2D mimetic divergence operator.
- class Div3D

  Implements a 3D mimetic divergence operator.
- class GLPKAdapter

  Adapter class for the GLPK API.
- class Grad1D

  Implements a 1D mimetic gradient operator.
- class Grad2D

  Implements a 2D mimetic gradient operator.
- class Grad3D

  Implements a 3D mimetic gradient operator.
- class Interp1D

  Implements a 1D interpolation operator.
- class Interp2D

  Implements a 2D interpolation operator.
- class Lap1D

  Implements a 1D mimetic Laplacian operator.

- class Lap2D

  Implements a 2D mimetic Laplacian operator.
- class Lap3D

  Implements a 3D mimetic Laplacian operator.
- class LAPACKAdapter

  Adapter class for the LAPACK API.
- class Matrix

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

  Implements a 1D mimetic quadrature.
- class RobinBCDescriptor1D

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

  Impose Robin boundary conditions on the operators and on the grids.
- class RobinBCDescriptor3D

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

  Tool manager class.
- class UniStgGrid1D

  Uniform 1D Staggered Grid.
- class UniStgGrid2D

  Uniform 2D Staggered Grid.
- class UniStgGrid3D

  Uniform 3D Staggered Grid.

Typedefs

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

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

  A function of a BC coefficient evaluated on a 1D domain and time.
- typedef Real(∗ CoefficientFunction2D)(const Real &xx, const Real &yy, const Real &tt)

  A function of a BC coefficient evaluated on a 2D domain and time.
- typedef float Real

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

Enumerations

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

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

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

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

  Interpolation operator.

Functions

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

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

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

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

Variables

- const float kZero {0.0f}

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

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

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

  Considered tolerance for comparisons in numerical methods.
- const float kDefaultMimeticThreshold {1e-6f}

  Default tolerance for higher-order mimetic operators.
- const int kDefaultOrderAccuracy {2}

  Default order of accuracy for mimetic operators.
- const int kCriticalOrderAccuracyGrad {10}

  At this order (and higher) we must use the CBSA to construct gradients.
- const int kCriticalOrderAccuracyDiv {8}

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

16.1.1 Function Documentation

16.1.1.1 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.

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

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

Definition at line 67 of file mtk_uni_stg_grid_3d.cc.

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

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

Definition at line 67 of file mtk_uni_stg_grid_2d.cc.

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

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

Definition at line 68 of file mtk_uni_stg_grid_1d.cc.

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

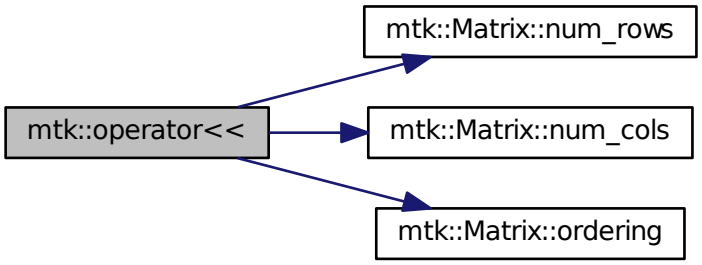
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 75 of file mtk_lap_1d.cc.

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

Definition at line 79 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



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

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

Definition at line 84 of file mtk_grad_1d.cc.

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

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

Definition at line 84 of file mtk_div_1d.cc.

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

Here is the caller graph for this function:

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

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

The following options are provided:

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

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

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

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

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

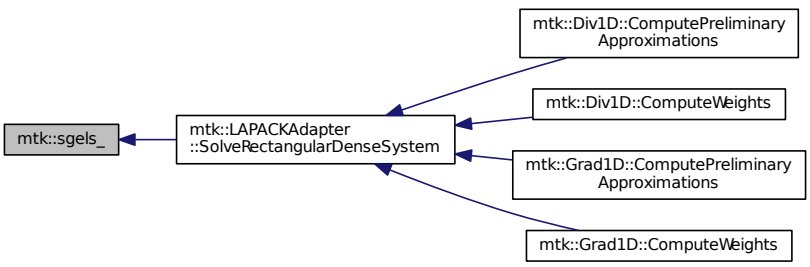
See also

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

Parameters

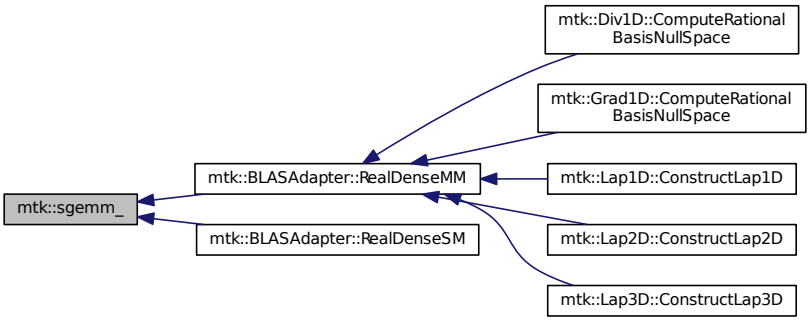
in	*trans*	Am I giving the transpose of the matrix?
in	*m*	The number of rows of the matrix a. m >= 0.
in	*n*	The number of columns of the matrix a. n >= 0.
in	*nrhs*	The number of right-hand sides.
in,out	*a*	On entry, the m-by-n matrix a.
in	*lda*	The leading dimension of a. lda >= max(1,m).
in,out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

Here is the caller graph for this function:



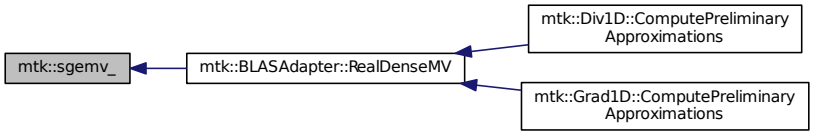
16.1.1.11 void mtk::sgemm_ (char * *transa*, char * *transb*, int * *m*, int * *n*, int * *k*, double * *alpha*, double * *a*, int * *lda*, double * *b*, aamm int * *ldb*, double * *beta*, double * *c*, int * *ldc*)

Here is the caller graph for this function:



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

Here is the caller graph for this function:



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

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

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

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

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

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

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

See also

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

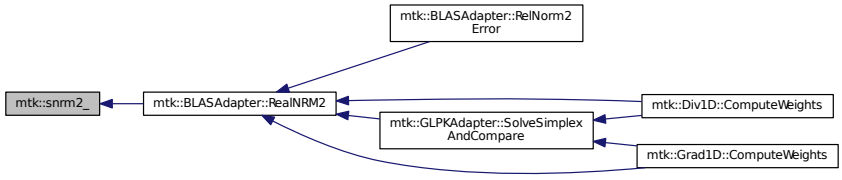
Parameters

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

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

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

Here is the caller graph for this function:



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

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

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

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

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

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

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

See also

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

Parameters

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

Chapter 17

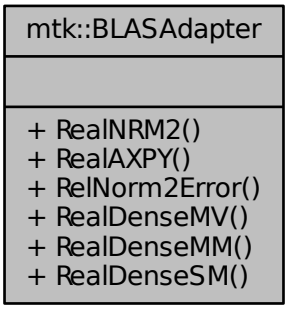
Class Documentation

17.1 mtk::BLASAdapter Class Reference

Adapter class for the BLAS API.

`#include <mtk_blas_adapter.h>`

Collaboration diagram for mtk::BLASAdapter:



Static Public Member Functions

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

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

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

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

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

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

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

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

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

17.1.1 Detailed Description

This class contains a collection of static member functions, 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/
https://software.intel.com/en-us/non-commercial-software-development

Definition at line 99 of file mtk_blas_adapter.h.

17.1.2 Member Function Documentation

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

Performs

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

Parameters

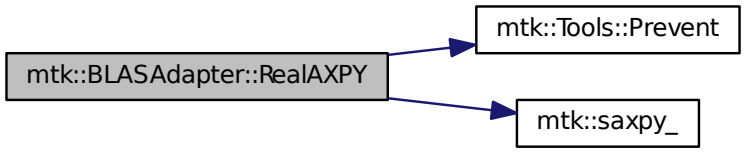
in	*alpha*	Scalar of the first array.
in	*xx*	First array.
in	*yy*	Second array.
in	*in_length*	Lengths of the given arrays.

Returns

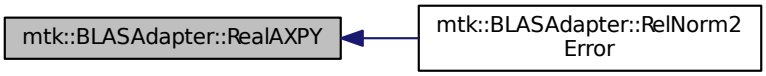
Norm-2 of the given array.

Definition at line 342 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs:

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

Parameters

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

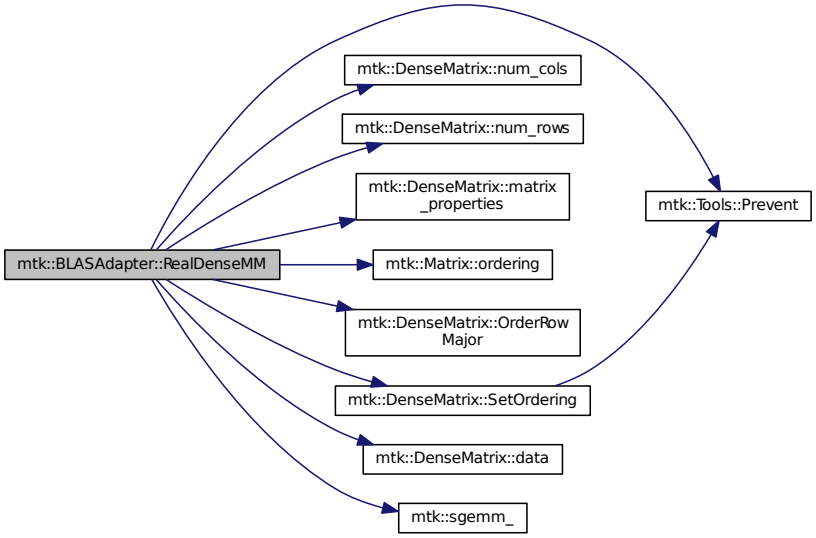
See also

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

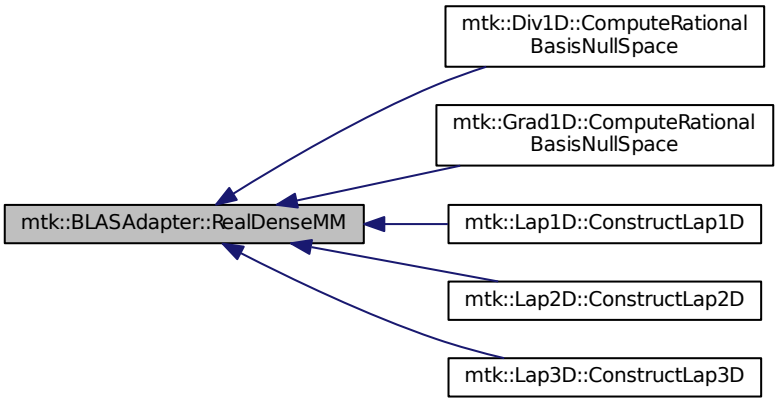
1. Make sure input matrices are row-major ordered.
2. Setup the problem.
3. Perform multiplication.

Definition at line 412 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs

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

Parameters

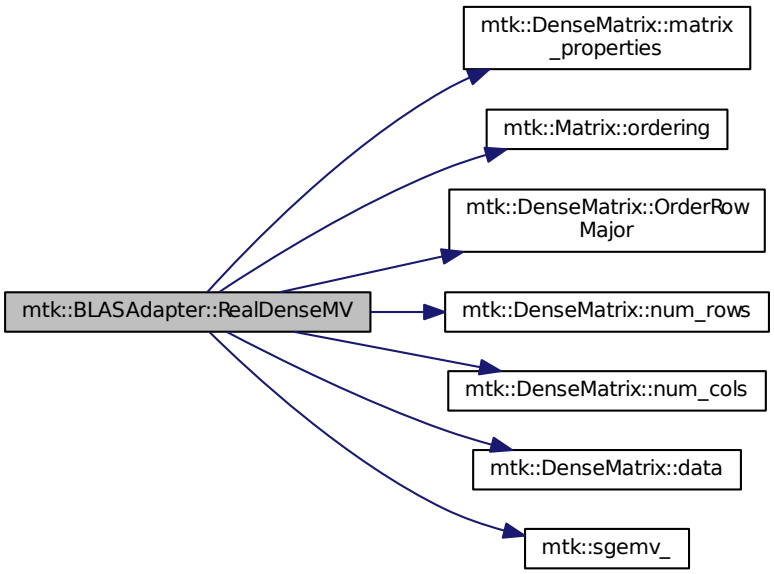
in	*alpha*	First scalar.
in	*aa*	Given matrix.
in	*xx*	First vector.
in	*beta*	Second scalar.
in,out	*yy*	Second vector (output).

See also

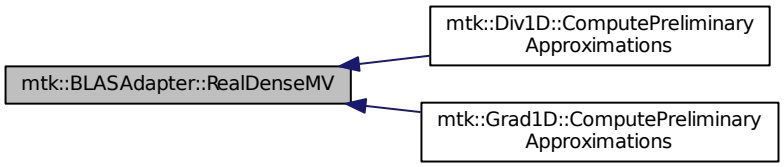
http://ejspeiro.github.io/Netlib-and-CPP/

Definition at line 381 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs:

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

Parameters

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

See also

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

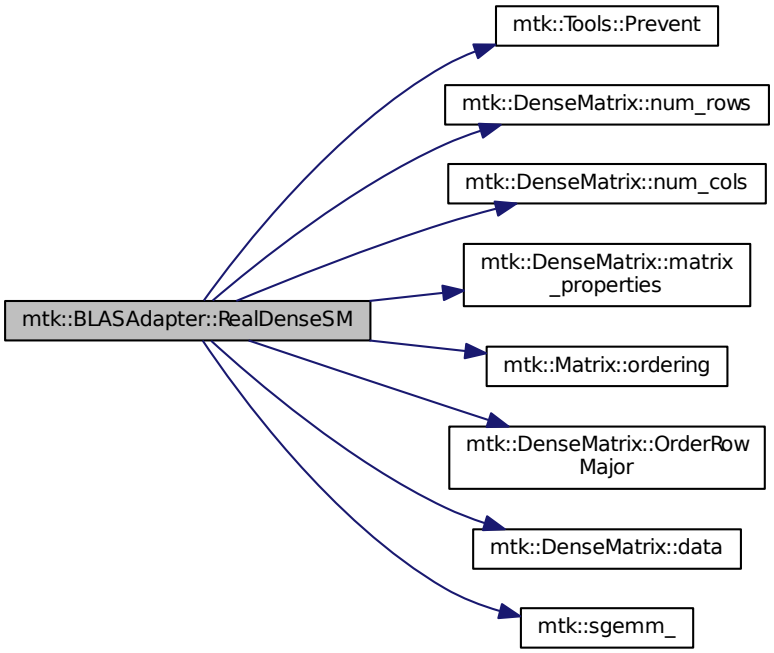
1. Make sure input matrices are row-major ordered.

2. Setup the problem.

3. Perform multiplication.

Definition at line 469 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



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

Parameters

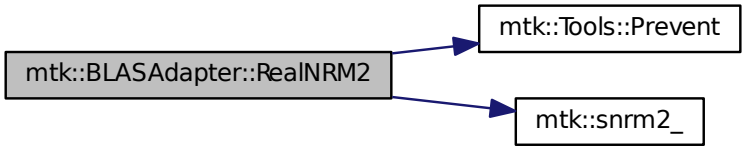
in	*in*	Input array.
in	*in_length*	Length of the array.

Returns

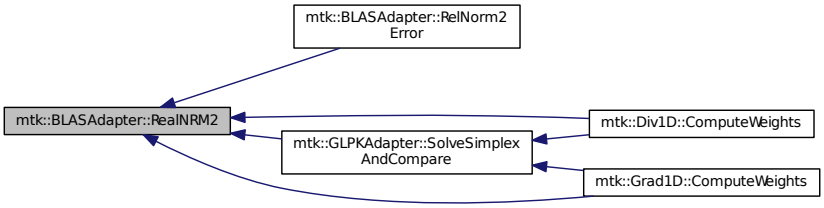
Norm-2 of the given array.

Definition at line 327 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

We compute

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

Parameters

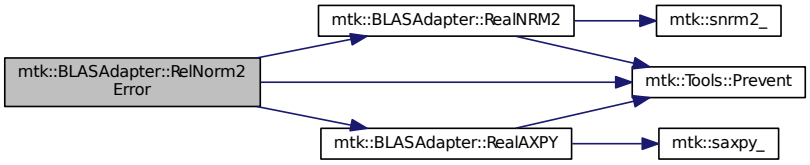
in	*known*	Array containing the computed solution.
in	*computed*	Array containing the known solution (ref. solution).

Returns

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

Definition at line 361 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:

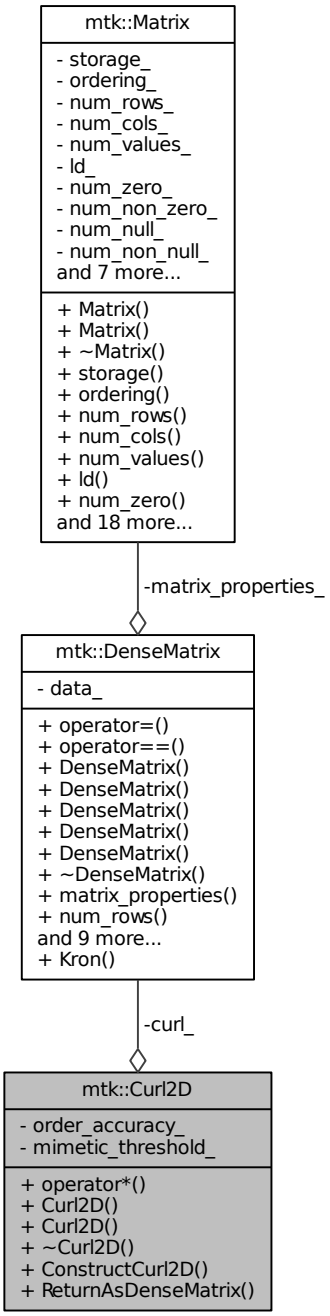
- include/mtk_blas_adapter.h
- src/mtk_blas_adapter.cc

17.2 mtk::Curl2D Class Reference

Implements a 2D mimetic curl operator.

`#include <mtk_curl_2d.h>`

Collaboration diagram for mtk::Curl2D:



Public Member Functions

- UniStgGrid3D operator∗ (const UniStgGrid2D &grid) const

Operator application operator on a grid.

- Curl2D ()

  Default constructor.

- Curl2D (const Curl2D &curl)

  Copy constructor.

- ~Curl2D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix curl_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.2.1 Detailed Description

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

Definition at line 77 of file mtk_curl_2d.h.

17.2.2 Constructor & Destructor Documentation

17.2.2.1 mtk::Curl2D::Curl2D ( )

Definition at line 79 of file mtk_curl_2d.cc.

17.2.2.2 mtk::Curl2D::Curl2D (const Curl2D & *curl*)

Parameters

in	*curl*	Given curl.

Definition at line 83 of file mtk_curl_2d.cc.

17.2.2.3 mtk::Curl2D::~Curl2D ( )

Definition at line 87 of file mtk_curl_2d.cc.

17.2.3 Member Function Documentation

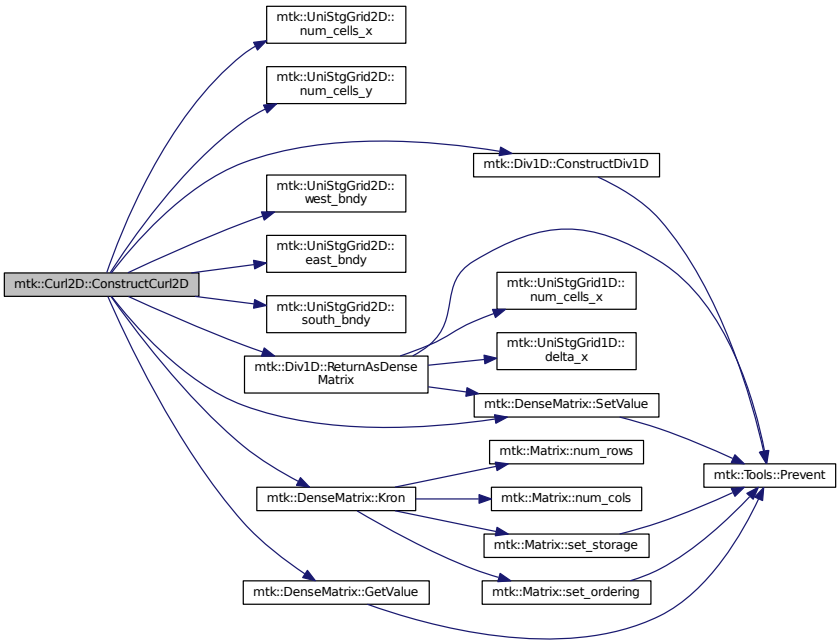
17.2.3.1 bool mtk::Curl2D::ConstructCurl2D (const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 89 of file mtk_curl_2d.cc.

Here is the call graph for this function:



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

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

Definition at line 70 of file mtk_curl_2d.cc.

17.2.3.3 mtk::DenseMatrix mtk::Curl2D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 157 of file mtk_curl_2d.cc.

17.2.4 Member Data Documentation

17.2.4.1 DenseMatrix mtk::Curl2D::curl_ [private]

Definition at line 112 of file mtk_curl_2d.h.

17.2.4.2 Real mtk::Curl2D::mimetic_threshold_ [private]

Definition at line 116 of file mtk_curl_2d.h.

17.2.4.3 int mtk::Curl2D::order_accuracy_ [private]

Definition at line 114 of file mtk_curl_2d.h.

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

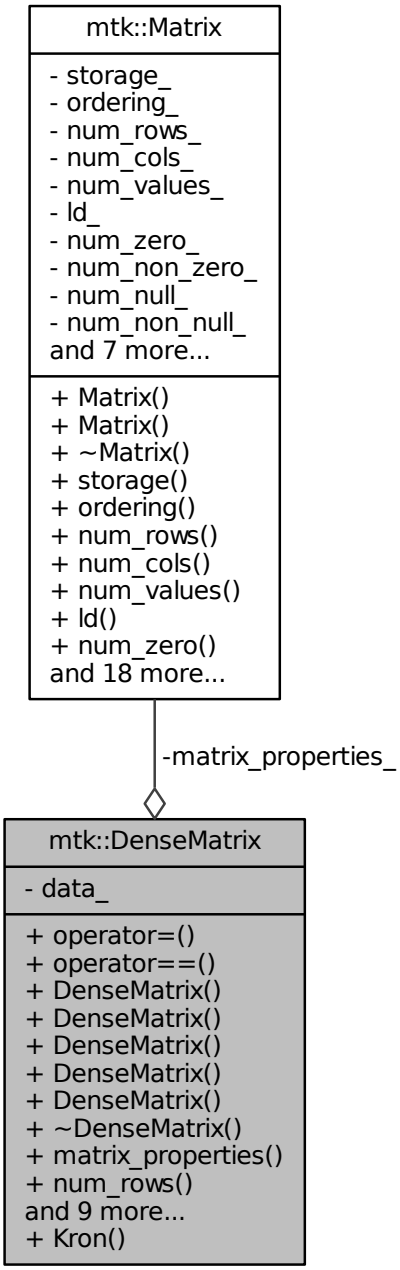
- include/mtk_curl_2d.h
- src/mtk_curl_2d.cc

17.3 mtk::DenseMatrix Class Reference

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

`#include <mtk_dense_matrix.h>`

Collaboration diagram for mtk::DenseMatrix:



Public Member Functions

- DenseMatrix & operator= (const DenseMatrix &in)

Overloaded assignment operator.

- bool operator== (const DenseMatrix &in)

  Am I equal to the in matrix?

- DenseMatrix ()

  Default constructor.

- DenseMatrix (const DenseMatrix &in)

  Copy constructor.

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

  Construct a dense matrix based on the given dimensions.

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

  Construct a zero-rows-padded identity matrix.

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

  Construct a dense Vandermonde matrix.

- ~DenseMatrix ()

  Destructor.

- Matrix matrix_properties () const noexcept

  Provides access to the matrix data.

- int num_rows () const noexcept

  Gets the number of rows.

- int num_cols () const noexcept

  Gets the number of columns.

- Real * data () const noexcept

  Provides access to the matrix value array.

- void SetOrdering (mtk::MatrixOrdering oo) noexcept

  Sets the ordering of the matrix.

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

  Gets a value on the given coordinates.

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

  Sets a value on the given coordinates.

- void Transpose ()

  Transpose this matrix.

- void OrderRowMajor ()

  Make the matrix row-wise ordered.

- void OrderColMajor ()

  Make the matrix column-wise ordered.

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

  Writes matrix to a file compatible with Gnuplot 4.6.

Static Public Member Functions

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

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

Private Attributes

- Matrix matrix_properties_

  Data related to the matrix nature.

- Real * data_

  Array holding the data in contiguous position in memory.

Friends

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

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

17.3.1 Detailed Description

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

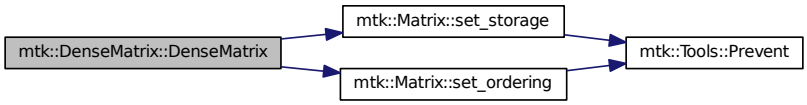
Definition at line 92 of file mtk_dense_matrix.h.

17.3.2 Constructor & Destructor Documentation

17.3.2.1 mtk::DenseMatrix::DenseMatrix ( )

Definition at line 167 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



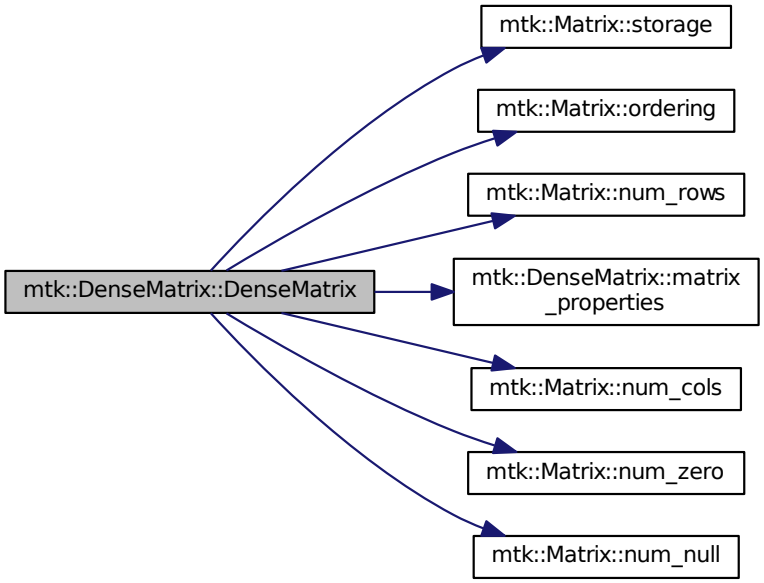
17.3.2.2 mtk::DenseMatrix::DenseMatrix (const DenseMatrix & *in*)

Parameters

in	*in*	Given matrix.

Definition at line 173 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 206 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

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

Used in the construction of the mimetic operators.

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

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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 228 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

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

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

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

This constructor generates a Vandermonde matrix, as defined above.

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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 269 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

17.3.2.6 mtk::DenseMatrix::~DenseMatrix ( )

Definition at line 317 of file mtk_dense_matrix.cc.

17.3.3 Member Function Documentation

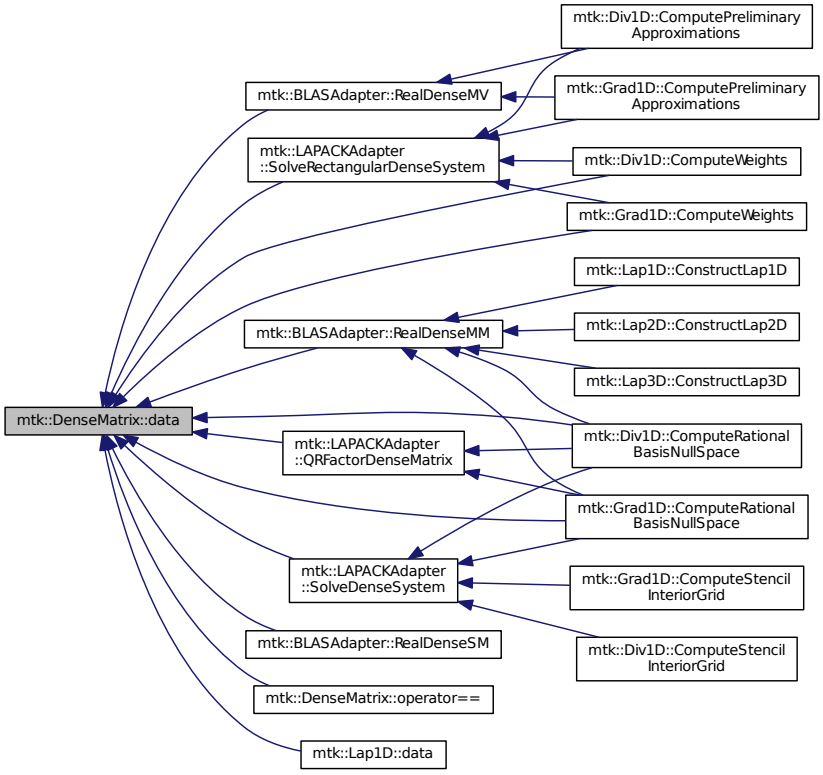
17.3.3.1 mtk::Real * mtk::DenseMatrix::data ( ) const [noexcept]

Returns

Pointer to an array of mtk::Real.

Definition at line 349 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



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

Parameters

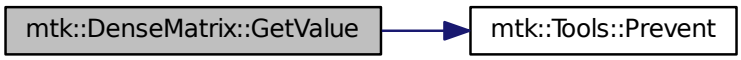
in	*row_coord*	Row coordinate.
in	*col_coord*	Column coordinate.

Returns

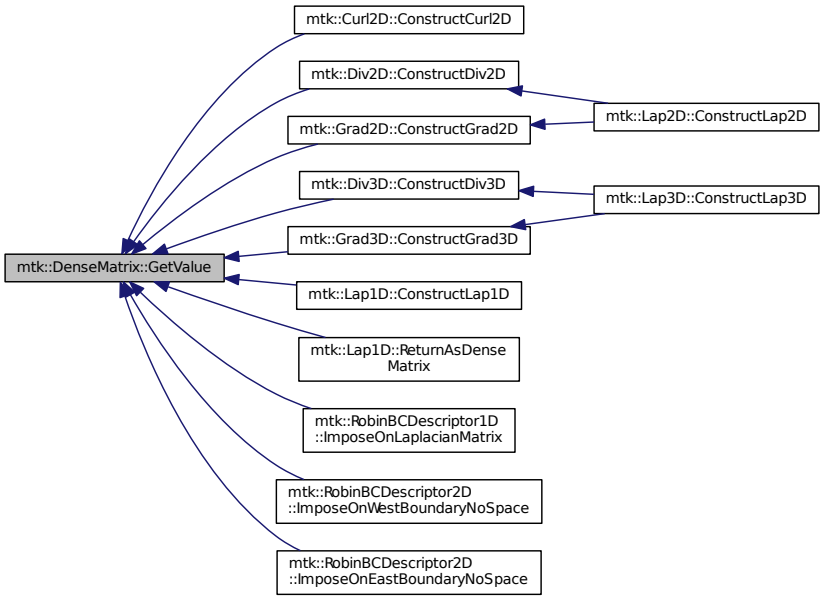
The required value at the specified coordinates.

Definition at line 354 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Parameters

in	*aa*	First matrix.

in	*bb*	Second matrix.

Exceptions

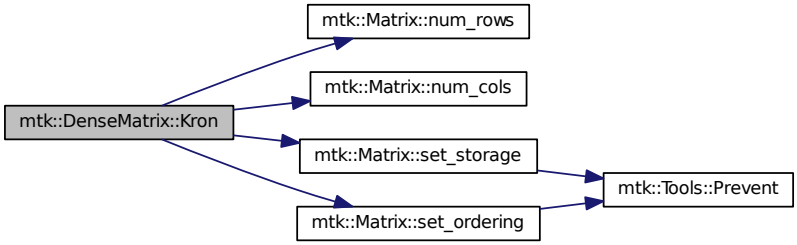
std::bad_alloc	

Todo Implement Kronecker product using the BLAS.

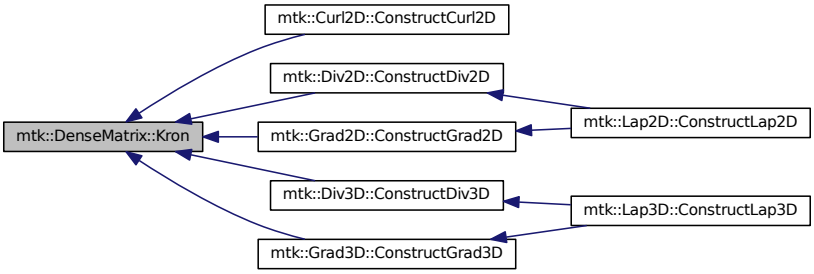
Todo Implement Kron using the BLAS.

Definition at line 496 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



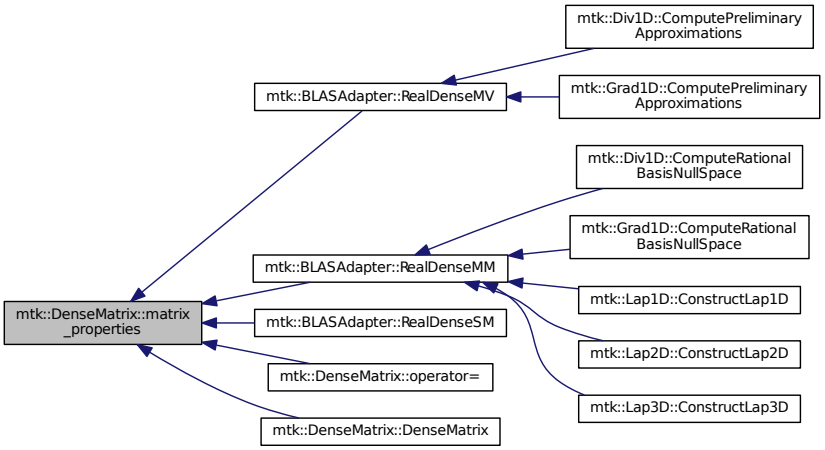
17.3.3.4 mtk::Matrix mtk::DenseMatrix::matrix_properties ( ) const [noexcept]

Returns

Pointer to a Matrix.

Definition at line 323 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



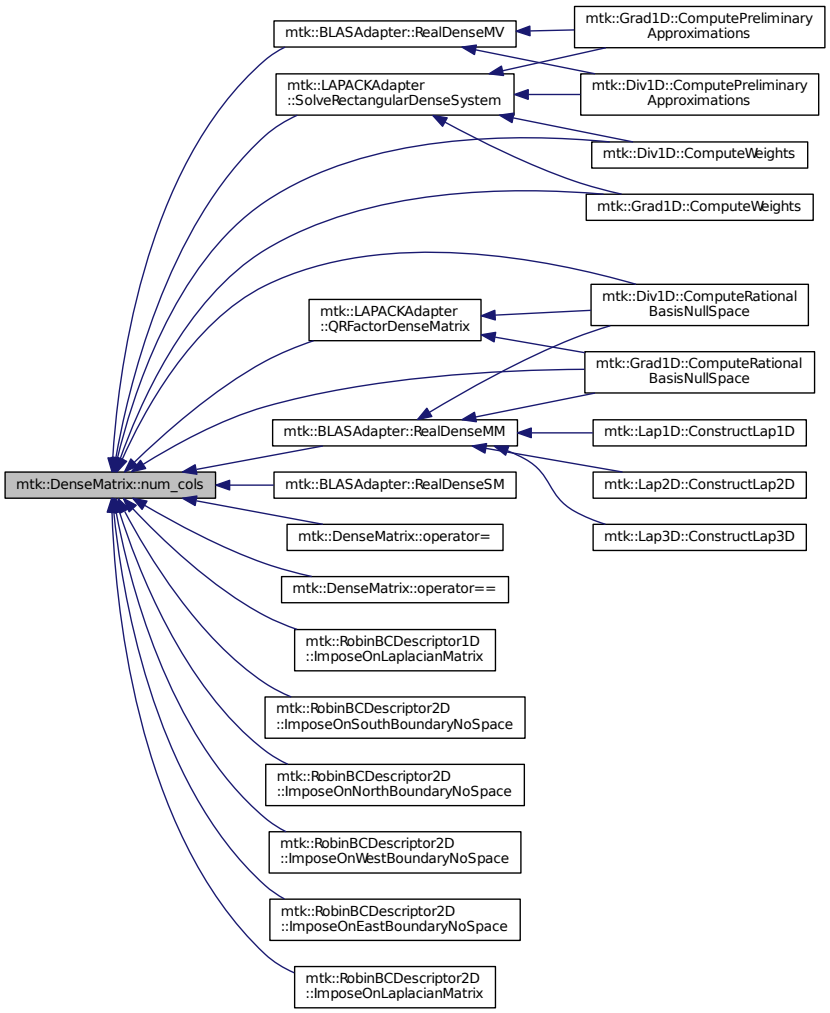
17.3.3.5 int mtk::DenseMatrix::num_cols ( ) const [noexcept]

Returns

Number of columns of the matrix.

Definition at line 344 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



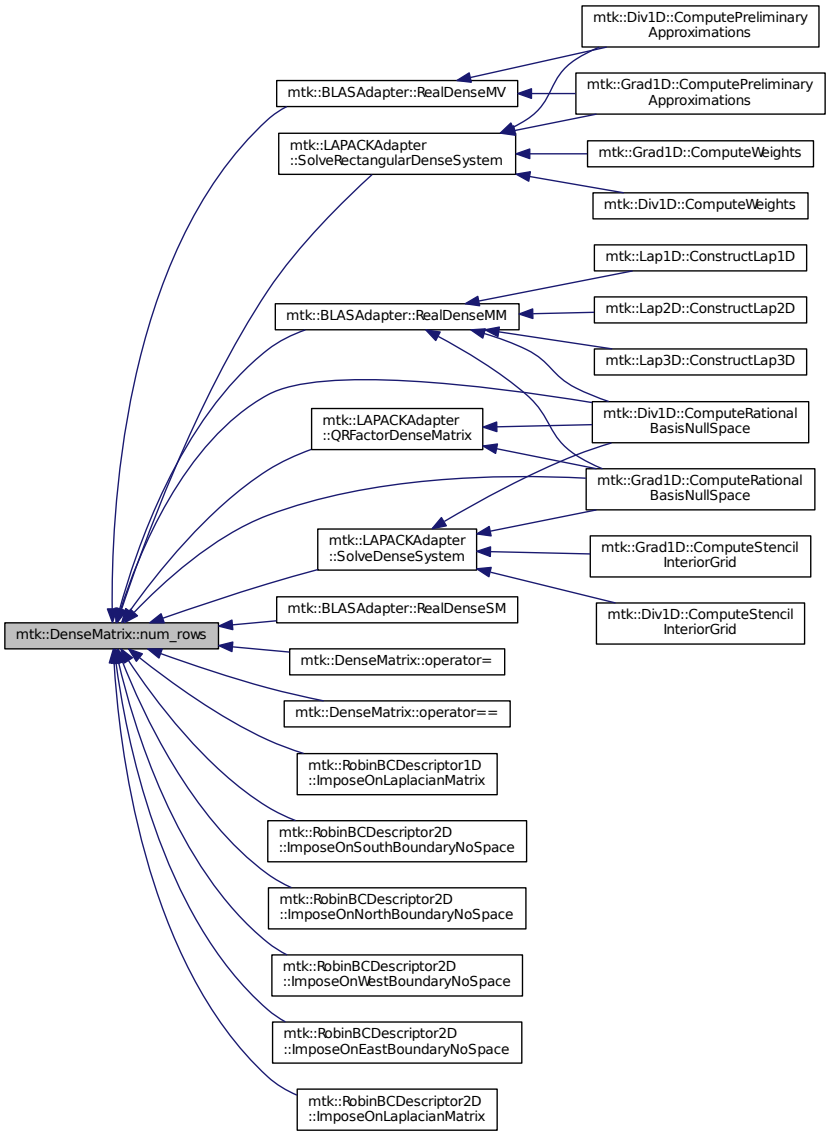
17.3.3.6 int mtk::DenseMatrix::num_rows ( ) const [noexcept]

Returns

Number of rows of the matrix.

Definition at line 339 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



17.3.3.7 mtk::DenseMatrix & mtk::DenseMatrix::operator= (const DenseMatrix & *in*)

Parameters

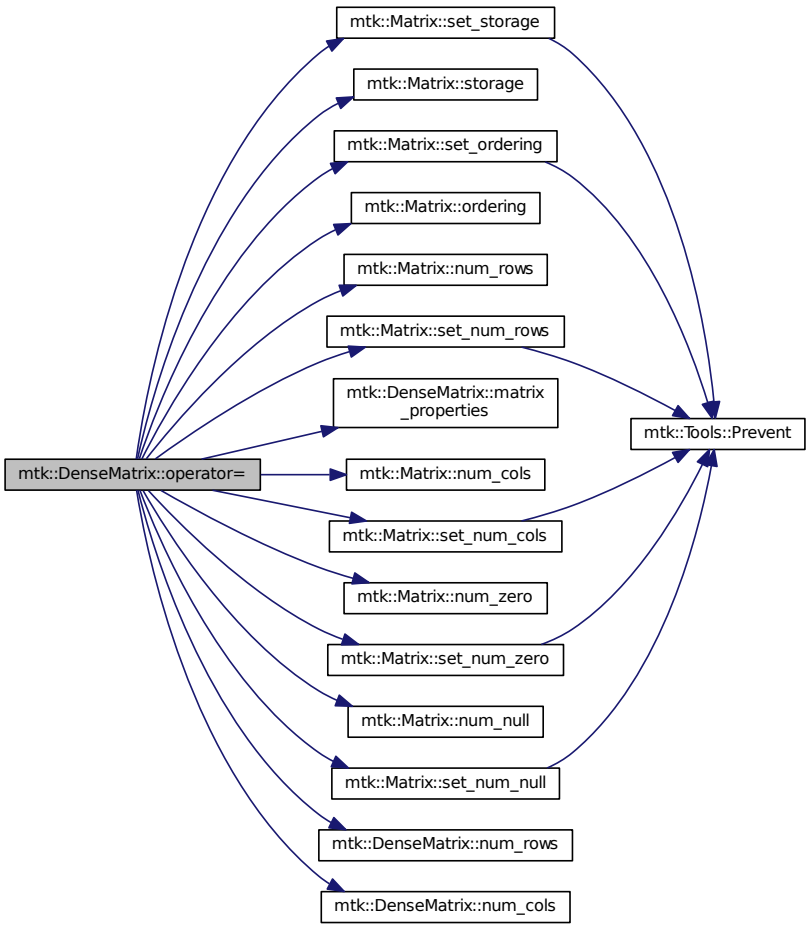
in	*in*	Given matrix.

Returns

Copy of the given matrix.

Definition at line 105 of file mtk_dense_matrix.cc.

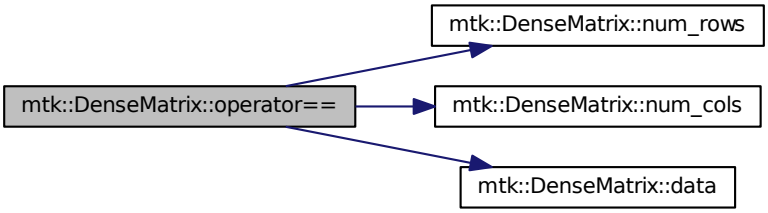
Here is the call graph for this function:



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

Definition at line 146 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

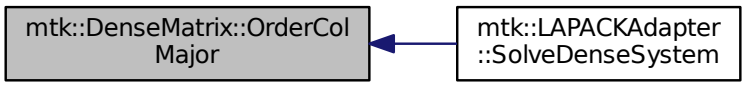


17.3.3.9 void mtk::DenseMatrix::OrderColMajor ( )

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

Definition at line 457 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:

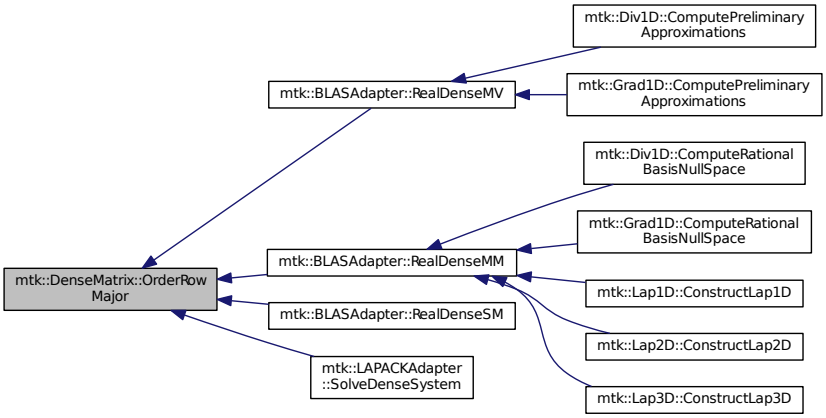


17.3.3.10 void mtk::DenseMatrix::OrderRowMajor ( )

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

Definition at line 416 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



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

Parameters

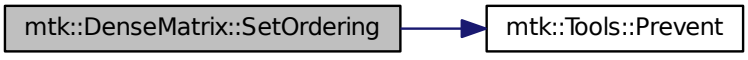
in	*oo*	Ordering.

Returns

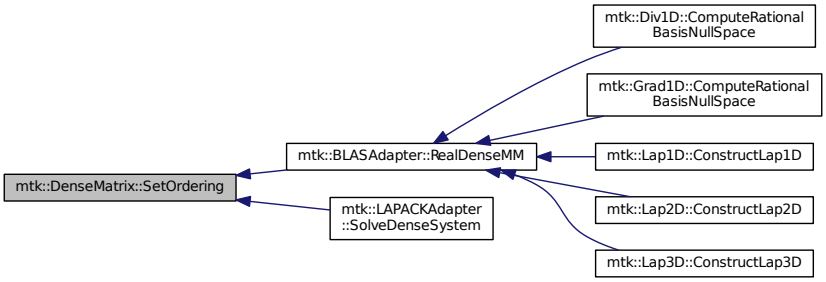
The required value at the specified coordinates.

Definition at line 328 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



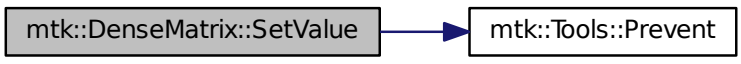
17.3.3.12 void mtk::DenseMatrix::SetValue (const int & *row_coord,* const int & *col_coord,* const **Real** & *val*) [noexcept]

Parameters

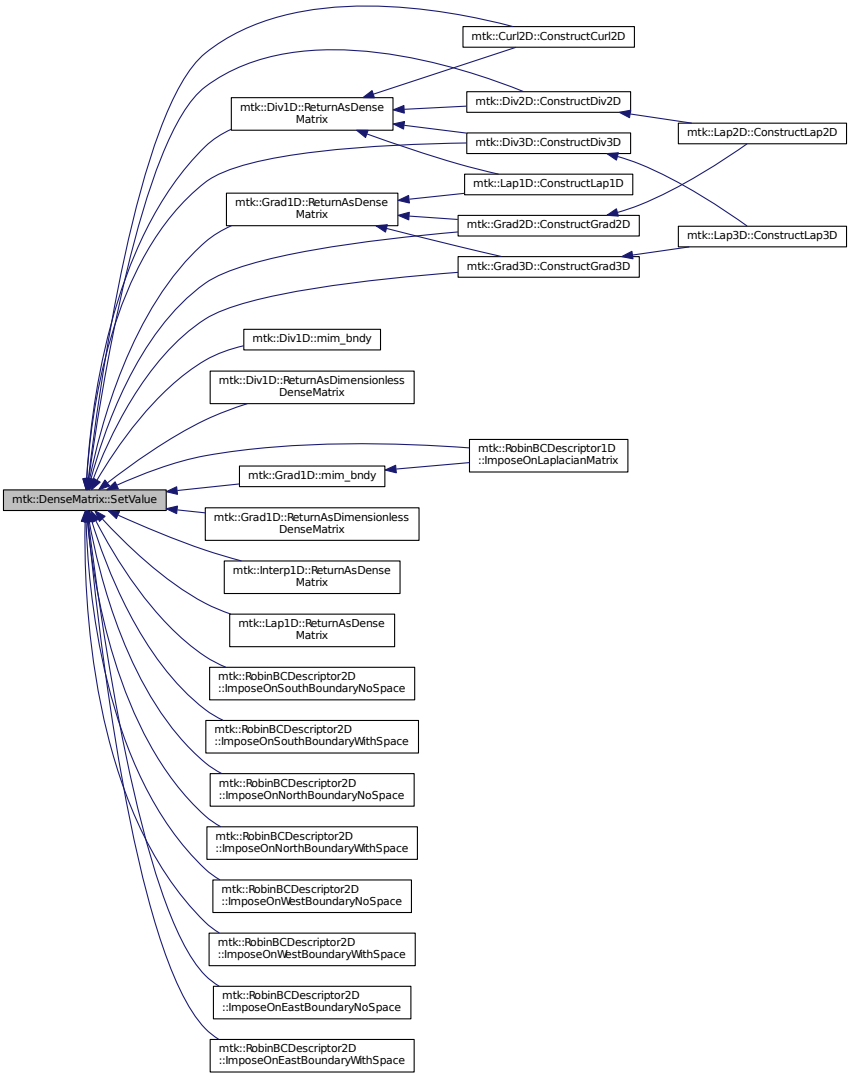
in	*row_coord*	Row coordinate.
in	*col_coord*	Column coordinate.
in	*val*	Row Actual value to be inserted.

Definition at line 366 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

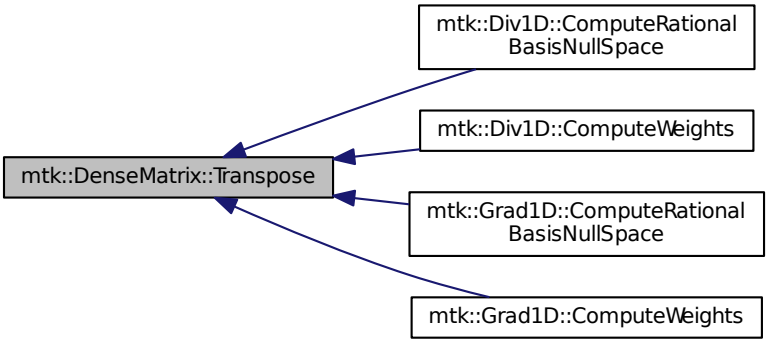


17.3.3.13 void mtk::DenseMatrix::Transpose ( )

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

Definition at line 379 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



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

Parameters

in	*filename*	Name of the output file.

Returns

Success of the file writing process.

See also

http://www.gnuplot.info/

Definition at line 539 of file mtk_dense_matrix.cc.

17.3.4 Friends And Related Function Documentation

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

Definition at line 79 of file mtk_dense_matrix.cc.

17.3.5 Member Data Documentation

17.3.5.1 Real* mtk::DenseMatrix::data_ [private]

Definition at line 291 of file mtk_dense_matrix.h.

17.3.5.2 Matrix mtk::DenseMatrix::matrix_properties_ [private]

Definition at line 289 of file mtk_dense_matrix.h.

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

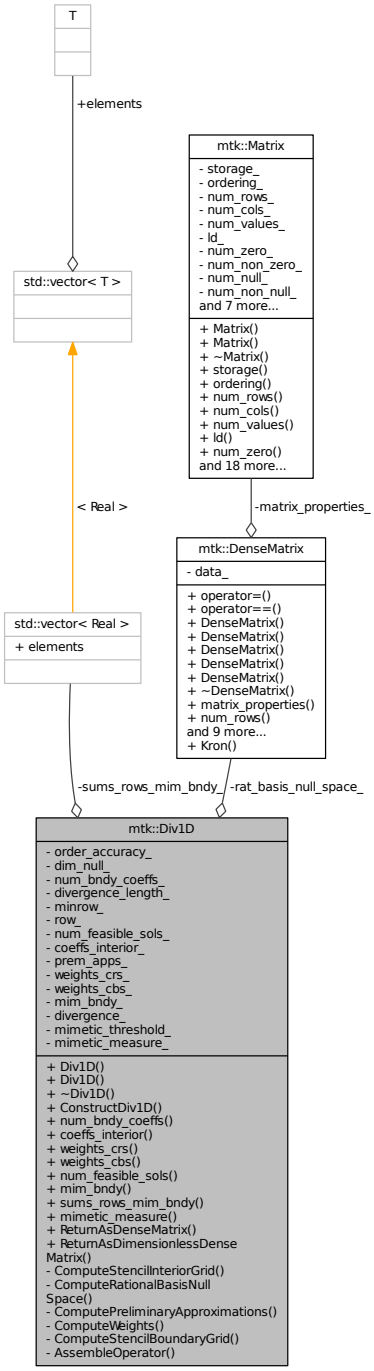
- include/mtk_dense_matrix.h
- src/mtk_dense_matrix.cc

17.4 mtk::Div1D Class Reference

Implements a 1D mimetic divergence operator.

`#include <mtk_div_1d.h>`

Collaboration diagram for mtk::Div1D:



Public Member Functions

- Div1D ()

Default constructor.

- Div1D (const Div1D &div)

  Copy constructor.

- ~Div1D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- int num_bndy_coeffs () const

  Returns how many coefficients are approximating at the boundary.

- Real * coeffs_interior () const

  Returns coefficients for the interior of the grid.

- Real * weights_crs (void) const

  Return collection of weights as computed by the CRSA.

- Real * weights_cbs (void) const

  Return collection of weights as computed by the CBSA.

- int num_feasible_sols () const

  Return number of feasible solutions when using the CBSA for weights.

- DenseMatrix mim_bndy () const

  Return collection of mimetic approximations at the boundary.

- std::vector< Real > sums_rows_mim_bndy () const

  Return collection of row-sums mimetic approximations at the boundary.

- Real mimetic_measure () const

  Returns mimetic measure of the operator.

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  Return the operator as a dense matrix.

- DenseMatrix ReturnAsDimensionlessDenseMatrix (int num_cells_x) const

  Returns the operator as a dimensionless dense matrix.

Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  Stage 1 of the CBS Algorithm.

- bool ComputeRationalBasisNullSpace (void)

  Stage 2.1 of the CBS Algorithm.

- bool ComputePreliminaryApproximations (void)

  Stage 2.2 of the CBS Algorithm.

- bool ComputeWeights (void)

  Stage 2.3 of the CBS Algorithm.

- bool ComputeStencilBoundaryGrid (void)

  Stage 2.4 of the CBS Algorithm.

- bool AssembleOperator (void)

  Stage 3 of the CBS Algorithm.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.
- int dim_null_

  Dim. null-space for boundary approximations.
- int num_bndy_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.
- int num_feasible_sols_

  Number of feasible solutions for weights.
- 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.
- Real mimetic_measure_

  < Mimetic measure.
- std::vector< Real > sums_rows_mim_bndy_

  Sum of each mimetic boundary row.

Friends

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

  Output stream operator for printing.

17.4.1 Detailed Description

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

Definition at line 83 of file mtk_div_1d.h.

17.4.2 Constructor & Destructor Documentation

17.4.2.1 mtk::Div1D::Div1D ( )

Definition at line 136 of file mtk_div_1d.cc.

17.4.2.2 mtk::Div1D::Div1D (const Div1D & *div*)

Parameters

in	*div*	Given divergence.

Definition at line 154 of file mtk_div_1d.cc.

17.4.2.3 mtk::Div1D::∼Div1D ( )

Definition at line 172 of file mtk_div_1d.cc.

17.4.3 Member Function Documentation

17.4.3.1 bool mtk::Div1D::AssembleOperator (void) [private]

Construct the output array with the operator and its weights.

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

Definition at line 1504 of file mtk_div_1d.cc.

17.4.3.2 mtk::Real * mtk::Div1D::coeffs_interior ( ) const

Returns

Coefficients for the interior of the grid.

Definition at line 337 of file mtk_div_1d.cc.

17.4.3.3 bool mtk::Div1D::ComputePreliminaryApproximations (void) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the dim_null near-the-boundary columns of the pi matrix.
3. Create the Vandermonde matrix for this iteration.
4. New order-selector vector (gets re-written with LAPACK solutions).

5. Solving TT∗rr = ob yields the columns rr of the KK matrix.

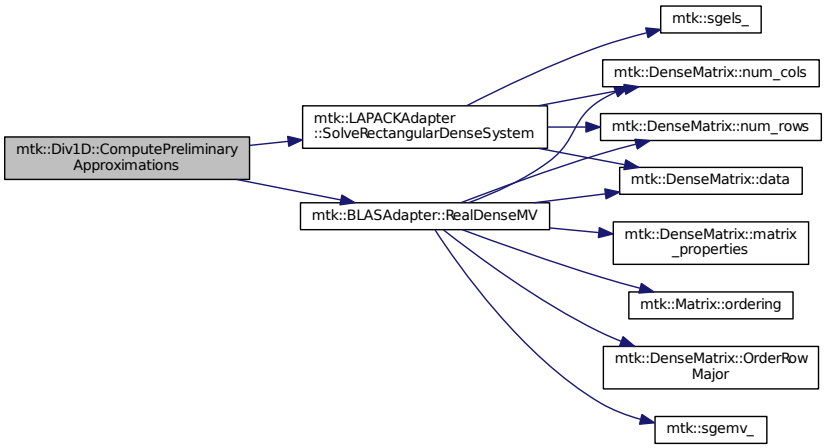
6. Scale the KK matrix to make it a rational basis for null-space.

7. Extract the last dim_null values of the pre-scaled ob.

8. Once we posses the bottom elements, we proceed with the scaling.

Definition at line 785 of file mtk_div_1d.cc.

Here is the call graph for this function:



17.4.3.4 bool mtk::Div1D::ComputeRationalBasisNullSpace (void) [private]

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

1. Create generator vector for the first approximation.

2. Create Vandermonde matrix.

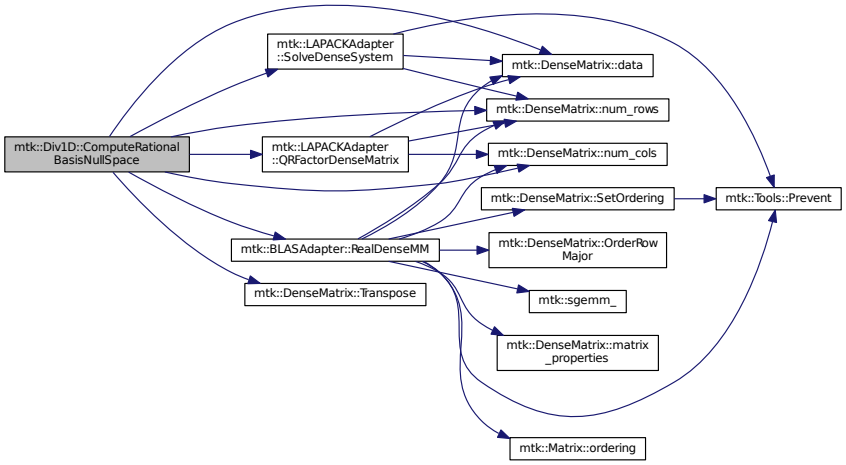
3. QR-factorize the Vandermonde matrix.

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

5. Scale null-space to make it rational.

Definition at line 609 of file mtk_div_1d.cc.

Here is the call graph for this function:



17.4.3.5 bool mtk::Div1D::ComputeStencilBoundaryGrid (void) [private]

Compute mimetic stencil approximating at boundary.

1. Collect lambda values.
2. Compute alpha values.
3. Compute the mimetic boundary approximations.
4. Compute the row-wise sum to double-check the operator is mimetic.

Definition at line 1382 of file mtk_div_1d.cc.

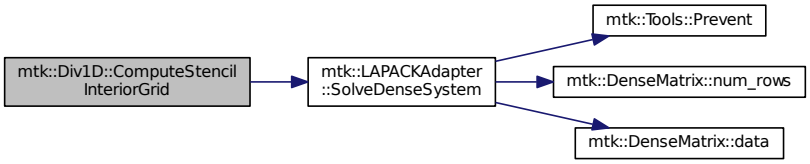
17.4.3.6 bool mtk::Div1D::ComputeStencilInteriorGrid (void) [private]

Compute the stencil approximating the interior of the staggered grid.

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

Definition at line 508 of file mtk_div_1d.cc.

Here is the call graph for this function:



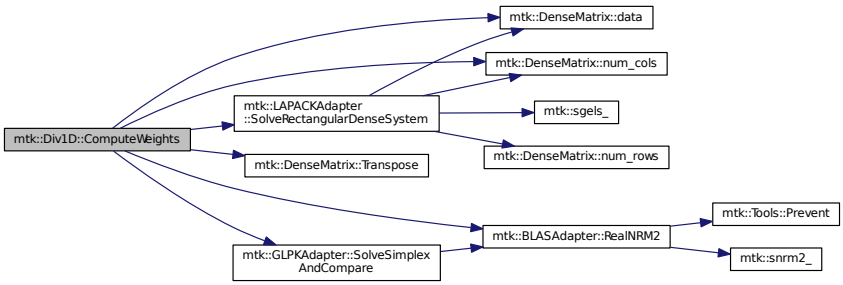
17.4.3.7 bool mtk::Div1D::ComputeWeights (void) [private]

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

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

Definition at line 1005 of file mtk_div_1d.cc.

Here is the call graph for this function:



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

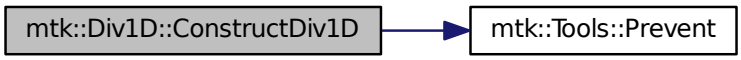
Returns

Success of the construction.

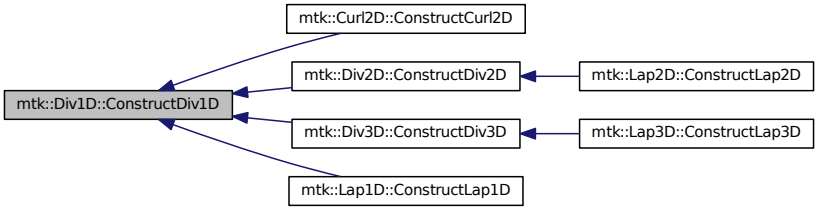
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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

Definition at line 193 of file mtk_div_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



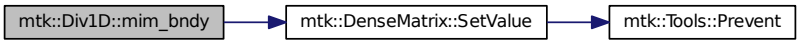
17.4.3.9 mtk::DenseMatrix mtk::Div1D::mim_bndy ( ) const

Returns

Collection of mimetic approximations at the boundary.

Definition at line 357 of file mtk_div_1d.cc.

Here is the call graph for this function:



17.4.3.10 mtk::Real mtk::Div1D::mimetic_measure ( ) const

Returns

Real number which is the mimetic measure of the operator.

Definition at line 377 of file mtk_div_1d.cc.

17.4.3.11 int mtk::Div1D::num_bndy_coeffs ( ) const

Returns

How many coefficients are approximating at the boundary.

Definition at line 332 of file mtk_div_1d.cc.

17.4.3.12 int mtk::Div1D::num_feasible_sols ( ) const

Returns

Return number of feasible solutions when using the CBSA for weights.

Definition at line 352 of file mtk_div_1d.cc.

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

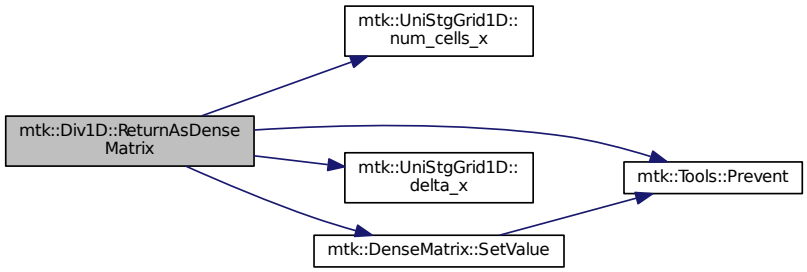
Returns

The operator as a dense matrix.

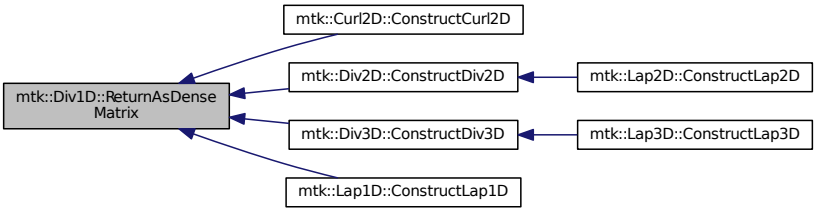
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 382 of file mtk_div_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



17.4.3.14 mtk::DenseMatrix mtk::Div1D::ReturnAsDimensionlessDenseMatrix (int *num_cells_x*) const

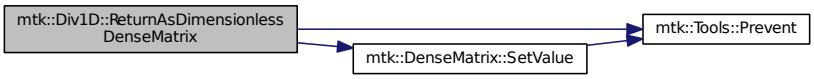
Returns

The operator as a dimensionless dense matrix.

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

Definition at line 446 of file mtk_div_1d.cc.

Here is the call graph for this function:



17.4.3.15 std::vector< mtk::Real > mtk::Div1D::sums_rows_mim_bndy ( ) const

Returns

Collection of row-sums mimetic approximations at the boundary.

Definition at line 372 of file mtk_div_1d.cc.

17.4.3.16 mtk::Real * mtk::Div1D::weights_cbs (void) const

Returns

Collection of weights as computed by the CBSA.

Definition at line 347 of file mtk_div_1d.cc.

17.4.3.17 mtk::Real * mtk::Div1D::weights_crs (void) const

Returns

Collection of weights as computed by the CRSA.

Definition at line 342 of file mtk_div_1d.cc.

17.4.4 Friends And Related Function Documentation

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

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

Definition at line 84 of file mtk_div_1d.cc.

17.4.5 Member Data Documentation

17.4.5.1 Real* mtk::Div1D::coeffs_interior_ [private]

Definition at line 233 of file mtk_div_1d.h.

17.4.5.2 int mtk::Div1D::dim_null_ [private]

Definition at line 224 of file mtk_div_1d.h.

17.4.5.3 Real* mtk::Div1D::divergence_ [private]

Definition at line 238 of file mtk_div_1d.h.

17.4.5.4 int mtk::Div1D::divergence_length_ [private]

Definition at line 226 of file mtk_div_1d.h.

17.4.5.5 Real* mtk::Div1D::mim_bndy_ [private]

Definition at line 237 of file mtk_div_1d.h.

17.4.5.6 Real mtk::Div1D::mimetic_measure_ [private]

Definition at line 241 of file mtk_div_1d.h.

17.4.5.7 Real mtk::Div1D::mimetic_threshold_ [private]

Definition at line 240 of file mtk_div_1d.h.

17.4.5.8 int mtk::Div1D::minrow_ [private]

Definition at line 227 of file mtk_div_1d.h.

17.4.5.9 int mtk::Div1D::num_bndy_coeffs_ [private]

Definition at line 225 of file mtk_div_1d.h.

17.4.5.10 int mtk::Div1D::num_feasible_sols_ [private]

Definition at line 229 of file mtk_div_1d.h.

17.4.5.11 int mtk::Div1D::order_accuracy_ [private]

Definition at line 223 of file mtk_div_1d.h.

17.4.5.12 Real* mtk::Div1D::prem_apps_ [private]

Definition at line 234 of file mtk_div_1d.h.

17.4.5.13 DenseMatrix mtk::Div1D::rat_basis_null_space_ [private]

Definition at line 231 of file mtk_div_1d.h.

17.4.5.14 int mtk::Div1D::row_ [private]

Definition at line 228 of file mtk_div_1d.h.

17.4.5.15 std::vector<Real> mtk::Div1D::sums_rows_mim_bndy_ [private]

Definition at line 243 of file mtk_div_1d.h.

17.4.5.16 Real* mtk::Div1D::weights_cbs_ [private]

Definition at line 236 of file mtk_div_1d.h.

17.4.5.17 Real* mtk::Div1D::weights_crs_ [private]

Definition at line 235 of file mtk_div_1d.h.

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

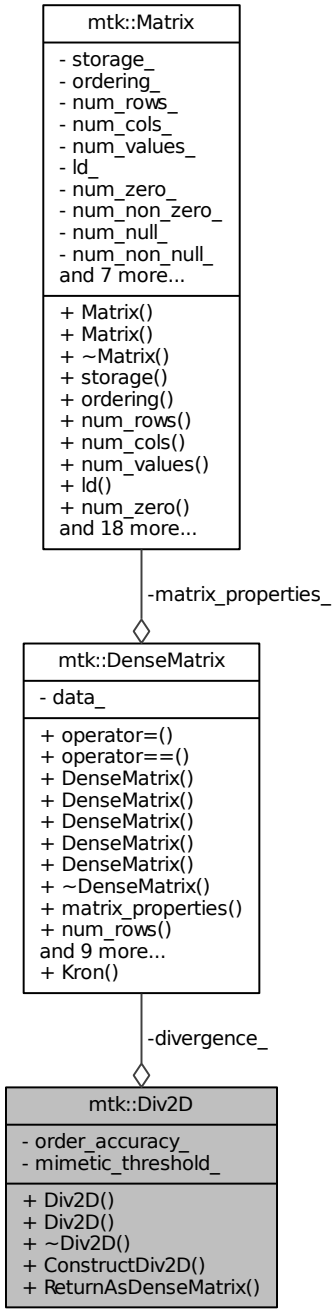
- include/mtk_div_1d.h
- src/mtk_div_1d.cc

17.5 mtk::Div2D Class Reference

Implements a 2D mimetic divergence operator.

`#include <mtk_div_2d.h>`

Collaboration diagram for mtk::Div2D:



Public Member Functions

- Div2D ()

Default constructor.

- Div2D (const Div2D &div)

  Copy constructor.

- ~Div2D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix divergence_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.5.1 Detailed Description

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

Definition at line 76 of file mtk_div_2d.h.

17.5.2 Constructor & Destructor Documentation

17.5.2.1 mtk::Div2D::Div2D ( )

Definition at line 69 of file mtk_div_2d.cc.

17.5.2.2 mtk::Div2D::Div2D (const Div2D & *div*)

Parameters

in	*div*	Given divergence.

Definition at line 73 of file mtk_div_2d.cc.

17.5.2.3 mtk::Div2D::~Div2D ( )

Definition at line 77 of file mtk_div_2d.cc.

17.5.3 Member Function Documentation

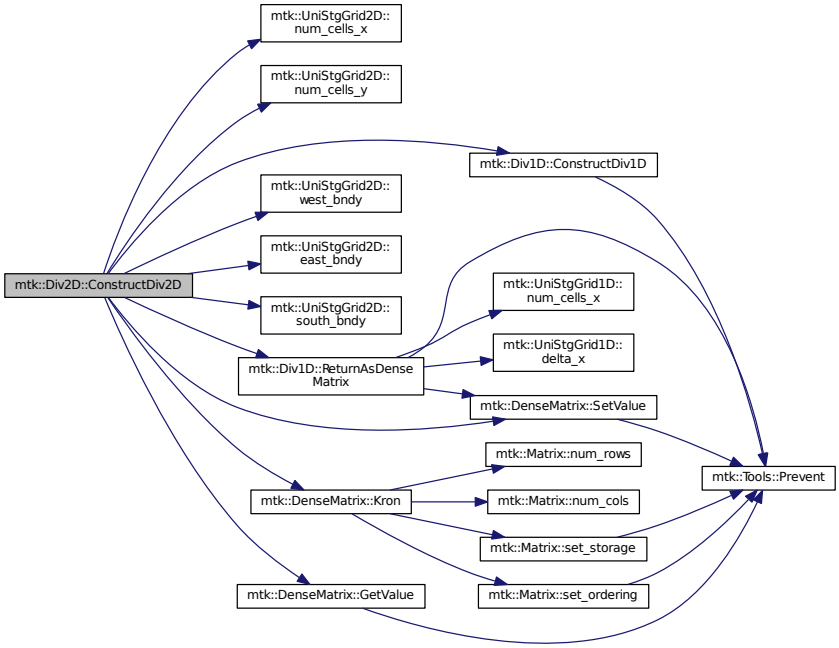
17.5.3.1 bool mtk::Div2D::ConstructDiv2D (const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 79 of file mtk_div_2d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

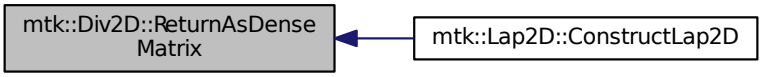
17.5.3.2 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 147 of file mtk_div_2d.cc.

Here is the caller graph for this function:



17.5.4 Member Data Documentation

17.5.4.1 DenseMatrix mtk::Div2D::divergence_ [private]

Definition at line 108 of file mtk_div_2d.h.

17.5.4.2 Real mtk::Div2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_div_2d.h.

17.5.4.3 int mtk::Div2D::order_accuracy_ [private]

Definition at line 110 of file mtk_div_2d.h.

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

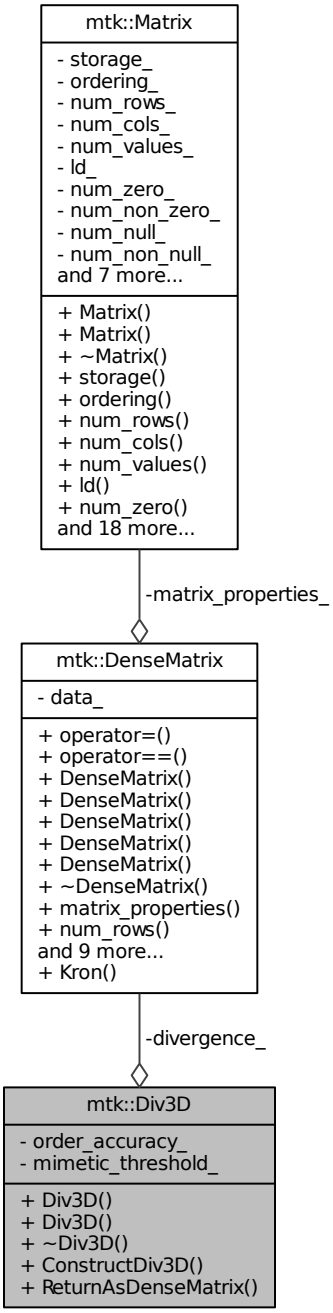
- include/mtk_div_2d.h
- src/mtk_div_2d.cc

17.6 mtk::Div3D Class Reference

Implements a 3D mimetic divergence operator.

`#include <mtk_div_3d.h>`

Collaboration diagram for mtk::Div3D:



Public Member Functions

- Div3D ()

Default constructor.

- Div3D (const Div3D &div)

  Copy constructor.

- ~Div3D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix divergence_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.6.1 Detailed Description

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

Definition at line 76 of file mtk_div_3d.h.

17.6.2 Constructor & Destructor Documentation

17.6.2.1 mtk::Div3D::Div3D ( )

Definition at line 67 of file mtk_div_3d.cc.

17.6.2.2 mtk::Div3D::Div3D (const Div3D & *div*)

Parameters

in	*div*	Given divergence.

Definition at line 71 of file mtk_div_3d.cc.

17.6.2.3 mtk::Div3D::~Div3D ( )

Definition at line 75 of file mtk_div_3d.cc.

17.6.3 Member Function Documentation

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

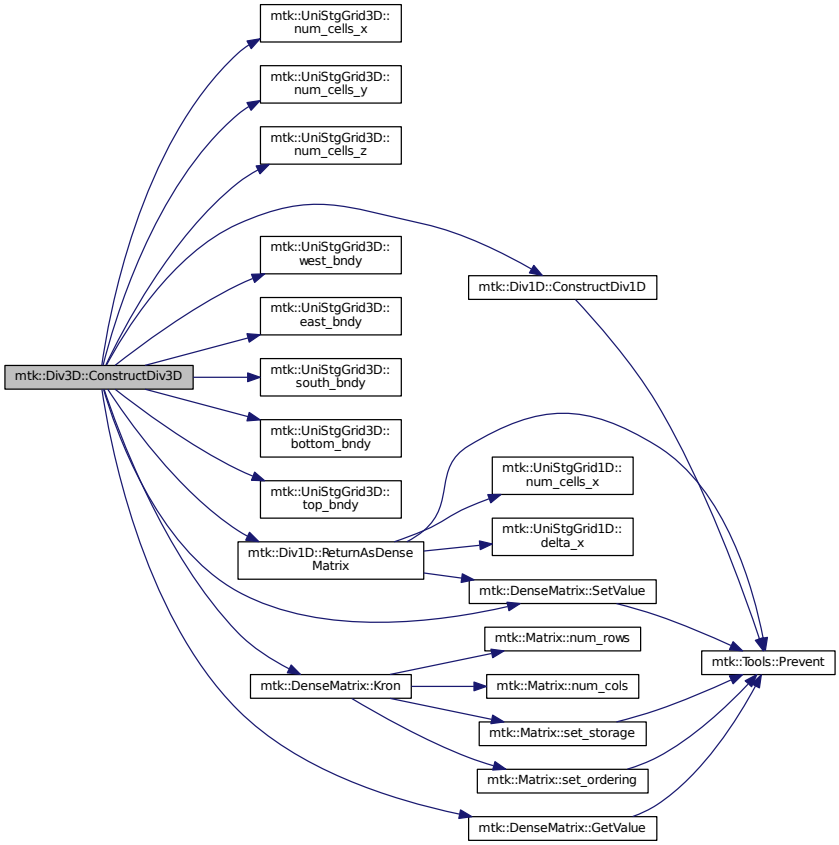
Returns

Success of the construction.

1. Build preliminary staggering through the x direction.
2. Build preliminary staggering through the y direction.
3. Build preliminary staggering through the z direction.
4. Actual operator: DD_xyz = [dx dy dz].

Definition at line 77 of file mtk_div_3d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

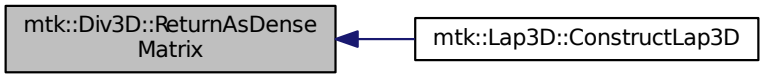
17.6.3.2 mtk::DenseMatrix mtk::Div3D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 186 of file mtk_div_3d.cc.

Here is the caller graph for this function:



17.6.4 Member Data Documentation

17.6.4.1 DenseMatrix mtk::Div3D::divergence_ [private]

Definition at line 108 of file mtk_div_3d.h.

17.6.4.2 Real mtk::Div3D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_div_3d.h.

17.6.4.3 int mtk::Div3D::order_accuracy_ [private]

Definition at line 110 of file mtk_div_3d.h.

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

- include/mtk_div_3d.h
- src/mtk_div_3d.cc

17.7 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 *AA, int nrows, int ncols, int kk, mtk::Real *hh, mtk::Real *qq, int robjective, mtk::Real mimetic_threshold, int copy) noexcept

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

17.7.1 Detailed Description

This class contains a collection of static member functions, 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 102 of file mtk_glpk_adapter.h.

17.7.2 Member Function Documentation

17.7.2.1 **mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare (mtk::Real * *AA,* int *nrows,* int *ncols,* int *kk,* mtk::Real * *hh,* mtk::Real * *qq,* int *robjective,* mtk::Real *mimetic_threshold,* int *copy*)** [static], [noexcept]

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	*AA*	Given matrix.
in	*nrows*	Number of rows of the matrix.
in	*ncols*	Number of rows of the matrix.
in	*kk*	Length of the RHS vector of constraints.
in	*hh*	RHS vector of constraints.
in,out	*qq*	Output decision vector.
in	*robjective*	Row of the system to be chosen as objective function.
in	*mimetic_threshold*	Mimetic threshold.
in	*copy*	Should we actually copy the results to the output?

Returns

Relative error computed between attained solution and provided ref.

Warning

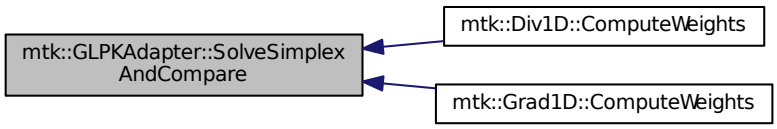
GLPK indexes in [1,n], so we must get the extra space needed.

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 77 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:

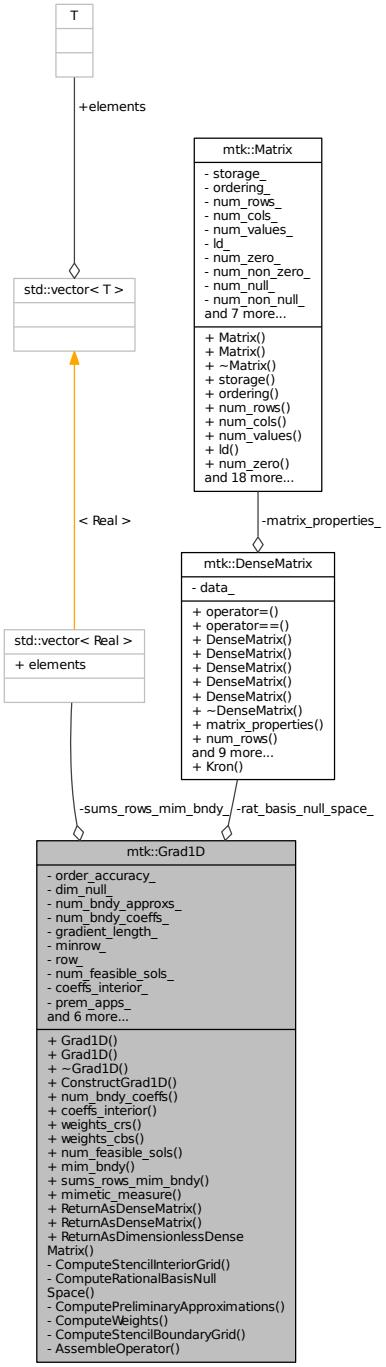
- include/mtk_glpk_adapter.h
- src/mtk_glpk_adapter.cc

17.8 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.

- int num_feasible_sols () const

  Return number of feasible solutions when using the CBSA for weights.

- DenseMatrix mim_bndy () const

  Return collection of mimetic approximations at the boundary.

- std::vector< Real > sums_rows_mim_bndy () const

  Return collection of row-sums mimetic approximations at the boundary.

- Real mimetic_measure () const

  Returns mimetic measure of the operator.

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

  Returns the operator as a dense matrix.

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  Returns the operator as a dense matrix.

- DenseMatrix ReturnAsDimensionlessDenseMatrix (int num_cells_x) const

  Returns the operator as a dimensionless dense matrix.

Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  Stage 1 of the CBS Algorithm.

- bool ComputeRationalBasisNullSpace (void)

  Stage 2.1 of the CBS Algorithm.

- bool ComputePreliminaryApproximations (void)

  Stage 2.2 of the CBS Algorithm.

- bool ComputeWeights (void)

  Stage 2.3 of the CBS Algorithm.

- bool ComputeStencilBoundaryGrid (void)

  Stage 2.4 of the CBS Algorithm.

- bool AssembleOperator (void)

  Stage 3 of the CBS Algorithm.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.
- int dim_null_

  Dim. null-space for boundary approximations.
- int num_bndy_approxs_

  Req. approximations at and near the boundary.
- int num_bndy_coeffs_

  Req. coeffs. per bndy pt. uni. order accuracy.
- int gradient_length_

  Length of the output array.
- int minrow_

  Row from the optimizer with the minimum rel. nor.
- int row_

  Row currently processed by the optimizer.
- int num_feasible_sols_

  Number of feasible solutions for weights.
- 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.
- Real mimetic_measure_

  < Mimetic measure.
- std::vector< Real > sums_rows_mim_bndy_

  Sum of each mimetic boundary row.

Friends

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

  Output stream operator for printing.

17.8.1 Detailed Description

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

Definition at line 83 of file mtk_grad_1d.h.

17.8.2 Constructor & Destructor Documentation

17.8.2.1 mtk::Grad1D::Grad1D ( )

Definition at line 148 of file mtk_grad_1d.cc.

17.8.2.2 mtk::Grad1D::Grad1D (const Grad1D & *grad*)

Parameters

in	*div*	Given divergence.

Definition at line 167 of file mtk_grad_1d.cc.

17.8.2.3 mtk::Grad1D::~Grad1D ( )

Definition at line 186 of file mtk_grad_1d.cc.

17.8.3 Member Function Documentation

17.8.3.1 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 1610 of file mtk_grad_1d.cc.

17.8.3.2 mtk::Real * mtk::Grad1D::coeffs_interior ( ) const

Returns

Coefficients for the interior of the grid.

Definition at line 351 of file mtk_grad_1d.cc.

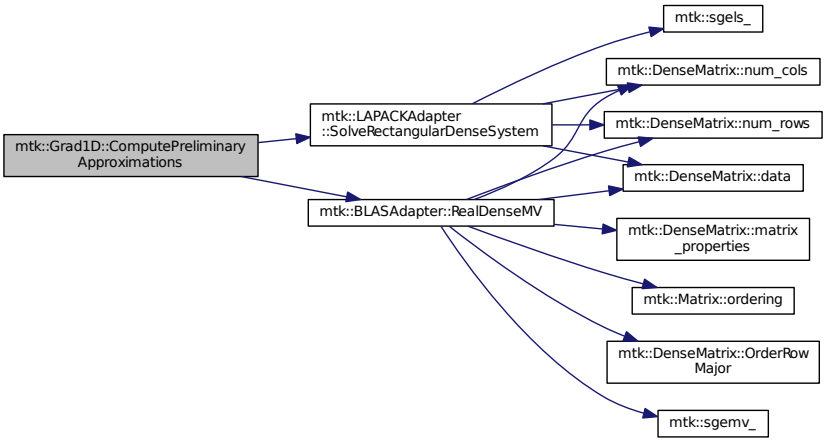
17.8.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations (void) [private]

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 871 of file mtk_grad_1d.cc.

Here is the call graph for this function:



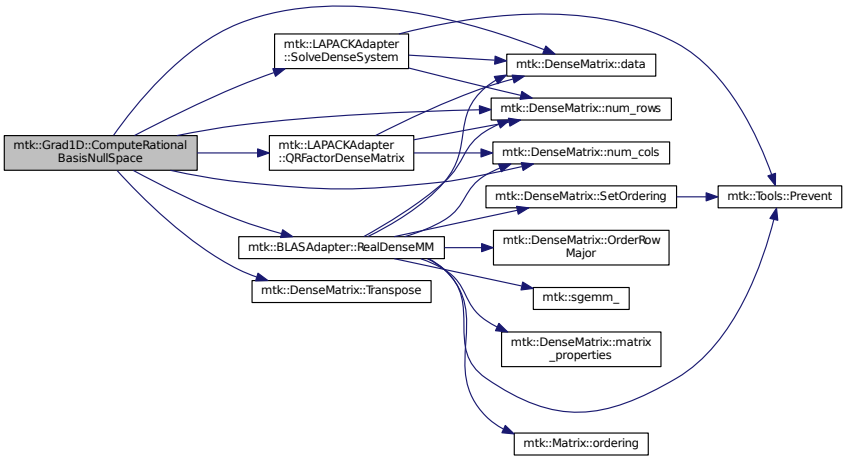
17.8.3.4 bool mtk::Grad1D::ComputeRationalBasisNullSpace (void) [private]

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 688 of file mtk_grad_1d.cc.

Here is the call graph for this function:



17.8.3.5 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.
4. Compute the row-wise sum to double-check that the operator is mimetic.

Definition at line 1479 of file mtk_grad_1d.cc.

17.8.3.6 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 591 of file mtk_grad_1d.cc.

Here is the call graph for this function:

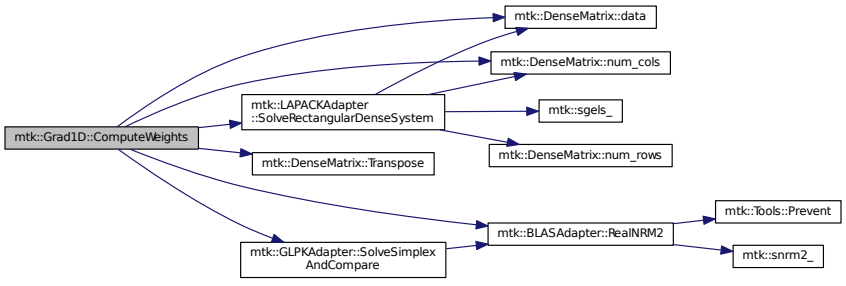
17.8.3.7 bool mtk::Grad1D::ComputeWeights (void) [private]

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 Φ matrix.
8. Apply solution found from brute force search.

Definition at line 1092 of file mtk_grad_1d.cc.

Here is the call graph for this function:



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

Returns

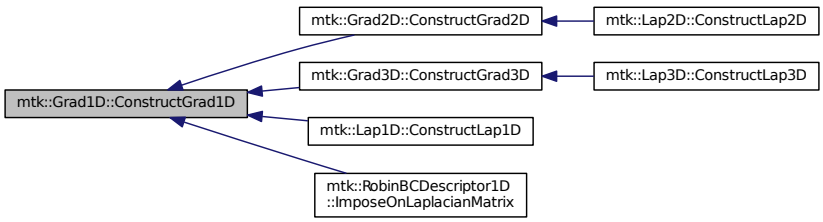
Success of the solution.

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 207 of file mtk_grad_1d.cc.

Here is the call graph for this function:

Here is the caller graph for this function:



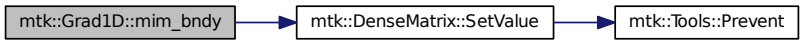
17.8.3.9 mtk::DenseMatrix mtk::Grad1D::mim_bndy ( ) const

Returns

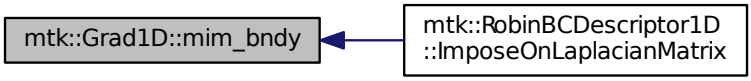
Collection of mimetic approximations at the boundary.

Definition at line 371 of file mtk_grad_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



17.8.3.10 mtk::Real mtk::Grad1D::mimetic_measure ( ) const

Returns

Real number which is the mimetic measure of the operator.

Definition at line 391 of file mtk_grad_1d.cc.

17.8.3.11 int mtk::Grad1D::num_bndy_coeffs ( ) const

Returns

How many coefficients are approximating at the boundary.

Definition at line 346 of file mtk_grad_1d.cc.

17.8.3.12 int mtk::Grad1D::num_feasible_sols ( ) const

Returns

Return number of feasible solutions when using the CBSA for weights.

Definition at line 366 of file mtk_grad_1d.cc.

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

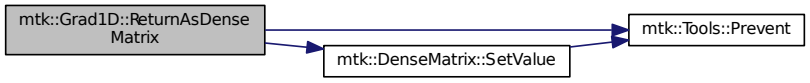
Returns

The operator as a dense matrix.

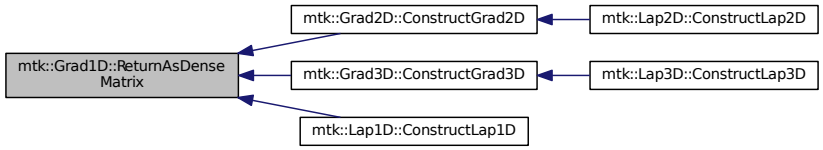
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 396 of file mtk_grad_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

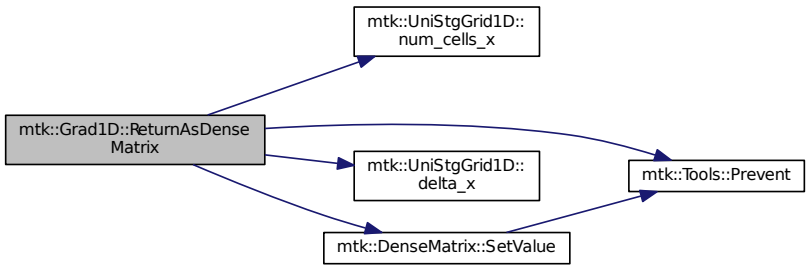
Returns

The operator as a dense matrix.

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

Definition at line 465 of file mtk_grad_1d.cc.

Here is the call graph for this function:



17.8.3.15 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix (int *num_cells_x*) const

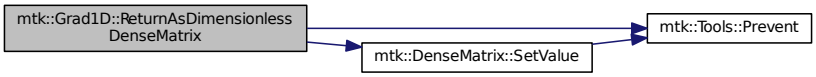
Returns

The operator as a dimensionless dense matrix.

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

Definition at line 529 of file mtk_grad_1d.cc.

Here is the call graph for this function:



17.8.3.16 std::vector< mtk::Real > mtk::Grad1D::sums_rows_mim_bndy ( ) const

Returns

Collection of row-sums mimetic approximations at the boundary.

Definition at line 386 of file mtk_grad_1d.cc.

17.8.3.17 mtk::Real * mtk::Grad1D::weights_cbs (void) const

Returns

Collection of weights as computed by the CBSA.

Definition at line 361 of file mtk_grad_1d.cc.

17.8.3.18 mtk::Real * mtk::Grad1D::weights_crs (void) const

Returns

Success of the solution.

Definition at line 356 of file mtk_grad_1d.cc.

17.8.4 Friends And Related Function Documentation

17.8.4.1 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 84 of file mtk_grad_1d.cc.

17.8.5 Member Data Documentation

17.8.5.1 Real* mtk::Grad1D::coeffs_interior_ [private]

Definition at line 241 of file mtk_grad_1d.h.

17.8.5.2 int mtk::Grad1D::dim_null_ [private]

Definition at line 231 of file mtk_grad_1d.h.

17.8.5.3 Real* mtk::Grad1D::gradient_ [private]

Definition at line 246 of file mtk_grad_1d.h.

17.8.5.4 int mtk::Grad1D::gradient_length_ [private]

Definition at line 234 of file mtk_grad_1d.h.

17.8.5.5 Real* mtk::Grad1D::mim_bndy_ [private]

Definition at line 245 of file mtk_grad_1d.h.

17.8.5.6 Real mtk::Grad1D::mimetic_measure_ [private]

Definition at line 249 of file mtk_grad_1d.h.

17.8.5.7 Real mtk::Grad1D::mimetic_threshold_ [private]

Definition at line 248 of file mtk_grad_1d.h.

17.8.5.8 int mtk::Grad1D::minrow_ [private]

Definition at line 235 of file mtk_grad_1d.h.

17.8.5.9 int mtk::Grad1D::num_bndy_approxs_ [private]

Definition at line 232 of file mtk_grad_1d.h.

17.8.5.10 int mtk::Grad1D::num_bndy_coeffs_ [private]

Definition at line 233 of file mtk_grad_1d.h.

17.8.5.11 int mtk::Grad1D::num_feasible_sols_ [private]

Definition at line 237 of file mtk_grad_1d.h.

17.8.5.12 int mtk::Grad1D::order_accuracy_ [private]

Definition at line 230 of file mtk_grad_1d.h.

17.8.5.13 Real* mtk::Grad1D::prem_apps_ [private]

Definition at line 242 of file mtk_grad_1d.h.

17.8.5.14 DenseMatrix mtk::Grad1D::rat_basis_null_space_ [private]

Definition at line 239 of file mtk_grad_1d.h.

17.8.5.15 int mtk::Grad1D::row_ [private]

Definition at line 236 of file mtk_grad_1d.h.

17.8.5.16 std::vector<Real> mtk::Grad1D::sums_rows_mim_bndy_ [private]

Definition at line 251 of file mtk_grad_1d.h.

17.8.5.17 Real* mtk::Grad1D::weights_cbs_ [private]

Definition at line 244 of file mtk_grad_1d.h.

17.8.5.18 Real* mtk::Grad1D::weights_crs_ [private]

Definition at line 243 of file mtk_grad_1d.h.

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

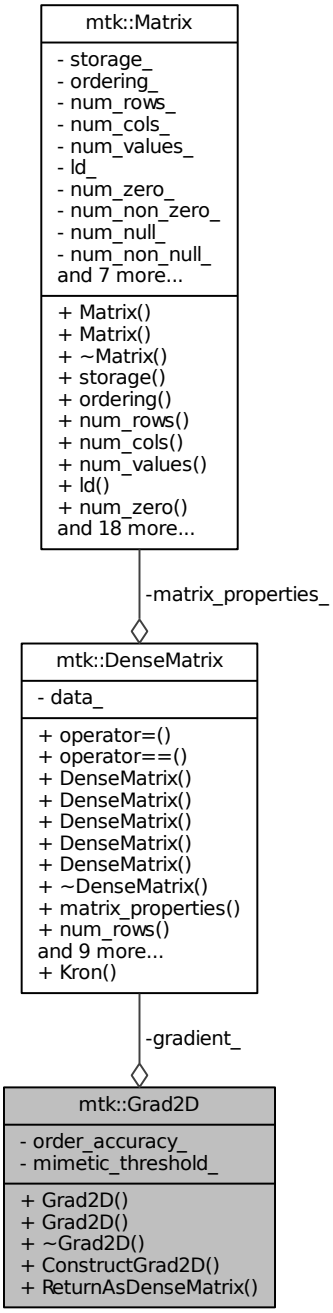
- include/mtk_grad_1d.h
- src/mtk_grad_1d.cc

17.9 mtk::Grad2D Class Reference

Implements a 2D mimetic gradient operator.

`#include <mtk_grad_2d.h>`

Collaboration diagram for mtk::Grad2D:



Public Member Functions

- Grad2D ()

Default constructor.

- Grad2D (const Grad2D &grad)

  Copy constructor.

- ~Grad2D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix gradient_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.9.1 Detailed Description

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

Definition at line 76 of file mtk_grad_2d.h.

17.9.2 Constructor & Destructor Documentation

17.9.2.1 mtk::Grad2D::Grad2D ( )

Definition at line 67 of file mtk_grad_2d.cc.

17.9.2.2 mtk::Grad2D::Grad2D (const Grad2D & *grad*)

Parameters

in	*div*	Given divergence.

Definition at line 71 of file mtk_grad_2d.cc.

17.9.2.3 mtk::Grad2D::~Grad2D ( )

Definition at line 75 of file mtk_grad_2d.cc.

17.9.3 Member Function Documentation

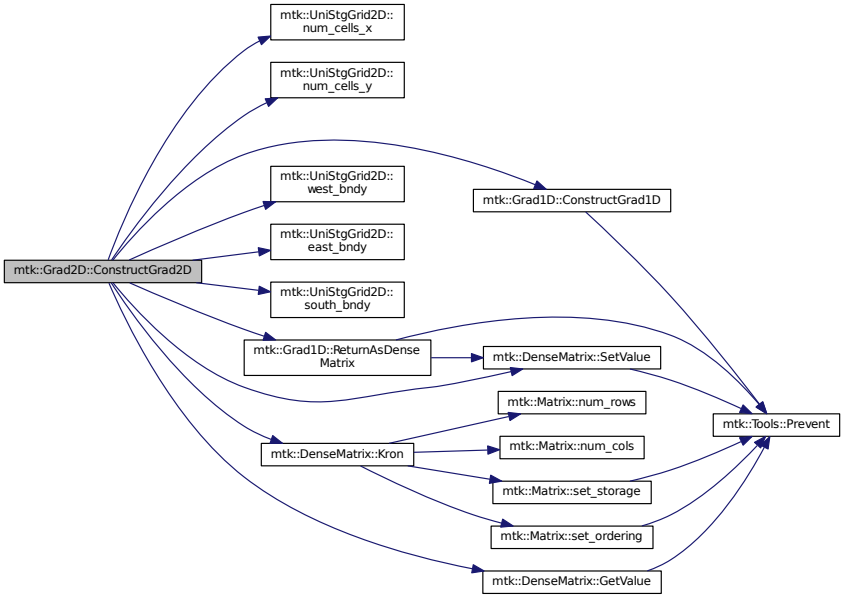
17.9.3.1 bool mtk::Grad2D::ConstructGrad2D (const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold)

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:

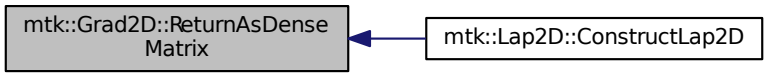
17.9.3.2 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 145 of file mtk_grad_2d.cc.

Here is the caller graph for this function:



17.9.4 Member Data Documentation

17.9.4.1 DenseMatrix mtk::Grad2D::gradient_ [private]

Definition at line 108 of file mtk_grad_2d.h.

17.9.4.2 Real mtk::Grad2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_grad_2d.h.

17.9.4.3 int mtk::Grad2D::order_accuracy_ [private]

Definition at line 110 of file mtk_grad_2d.h.

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

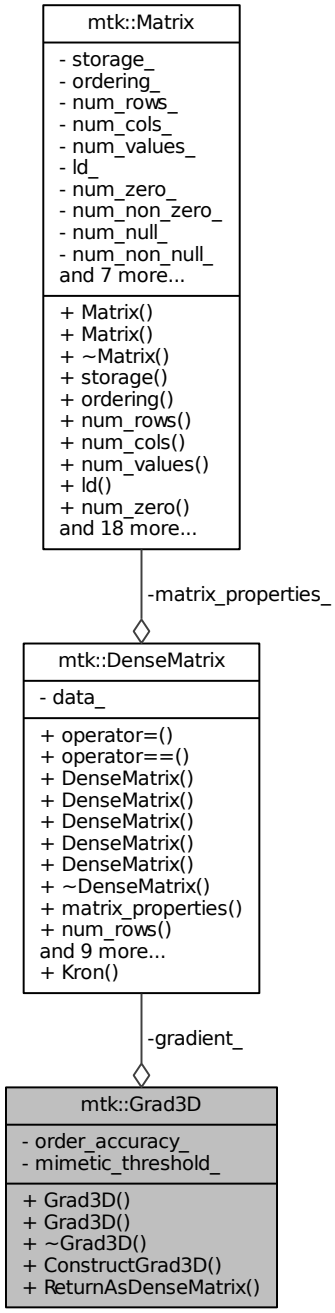
- include/mtk_grad_2d.h
- src/mtk_grad_2d.cc

17.10 mtk::Grad3D Class Reference

Implements a 3D mimetic gradient operator.

`#include <mtk_grad_3d.h>`

Collaboration diagram for mtk::Grad3D:



Public Member Functions

- Grad3D ()

Default constructor.

- Grad3D (const Grad3D &grad)

  Copy constructor.

- ~Grad3D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix gradient_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.10.1 Detailed Description

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

Definition at line 76 of file mtk_grad_3d.h.

17.10.2 Constructor & Destructor Documentation

17.10.2.1 mtk::Grad3D::Grad3D ( )

Definition at line 67 of file mtk_grad_3d.cc.

17.10.2.2 mtk::Grad3D::Grad3D (const Grad3D & *grad*)

Parameters

in	*div*	Given divergence.

Definition at line 71 of file mtk_grad_3d.cc.

17.10.2.3 mtk::Grad3D::~Grad3D ( )

Definition at line 75 of file mtk_grad_3d.cc.

17.10.3 Member Function Documentation

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

Returns

Success of the construction.

1. Build preliminary staggering through the x direction.

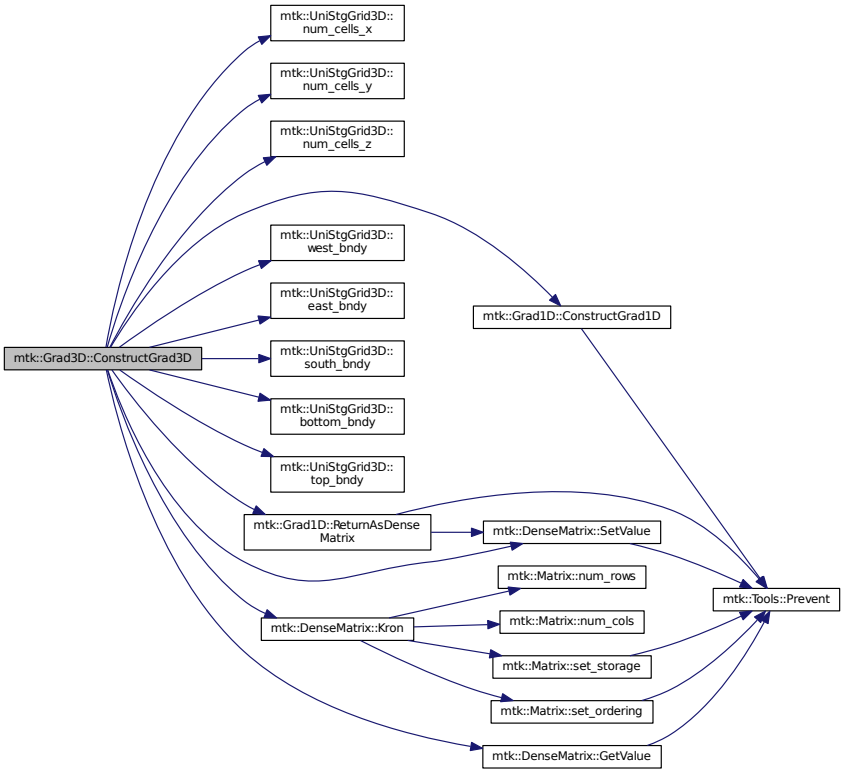
2. Build preliminary staggering through the y direction.

3. Build preliminary staggering through the z direction.

4. Actual operator: GG_xyz = [gx; gy; gz].

Definition at line 77 of file mtk_grad_3d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

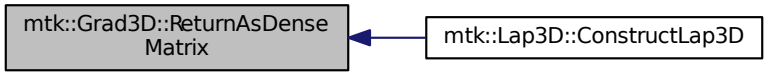
17.10.3.2 mtk::DenseMatrix mtk::Grad3D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 185 of file mtk_grad_3d.cc.

Here is the caller graph for this function:



17.10.4 Member Data Documentation

17.10.4.1 DenseMatrix mtk::Grad3D::gradient_ [private]

Definition at line 108 of file mtk_grad_3d.h.

17.10.4.2 Real mtk::Grad3D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_grad_3d.h.

17.10.4.3 int mtk::Grad3D::order_accuracy_ [private]

Definition at line 110 of file mtk_grad_3d.h.

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

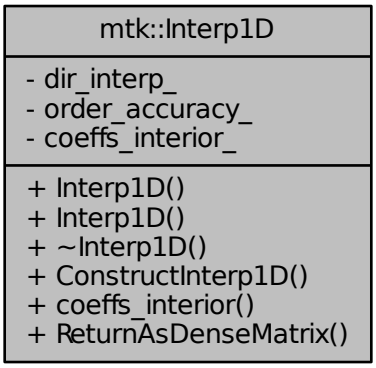
- include/mtk_grad_3d.h
- src/mtk_grad_3d.cc

17.11 mtk::Interp1D Class Reference

Implements a 1D interpolation operator.

`#include <mtk_interp_1d.h>`

Collaboration diagram for mtk::Interp1D:



Public Member Functions

- Interp1D ()
  Default constructor.
- Interp1D (const Interp1D &interp)
  Copy constructor.
- ~Interp1D ()
  Destructor.
- bool ConstructInterp1D (int order_accuracy=kDefaultOrderAccuracy, mtk::DirInterp dir=mtk::DirInterp::SCALAR_TO_VECTOR)
  Factory method to build operator.
- Real * coeffs_interior () const
  Returns coefficients for the interior of the grid.
- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const
  Returns the operator as a dense matrix.

Private Attributes

- DirInterp dir_interp_
  Direction of interpolation.
- int order_accuracy_
  Order of numerical accuracy of the operator.
- Real * coeffs_interior_
  Interior stencil.

Friends

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

  Output stream operator for printing.

17.11.1 Detailed Description

This class implements a 1D interpolation operator.

Definition at line 82 of file mtk_interp_1d.h.

17.11.2 Constructor & Destructor Documentation

17.11.2.1 mtk::Interp1D::Interp1D ( )

Definition at line 80 of file mtk_interp_1d.cc.

17.11.2.2 mtk::Interp1D::Interp1D (const Interp1D & *interp*)

Parameters

in	*interp*	Given interpolation operator.

Definition at line 85 of file mtk_interp_1d.cc.

17.11.2.3 mtk::Interp1D::~Interp1D ( )

Definition at line 90 of file mtk_interp_1d.cc.

17.11.3 Member Function Documentation

17.11.3.1 mtk::Real * mtk::Interp1D::coeffs_interior ( ) const

Returns

Coefficients for the interior of the grid.

Definition at line 132 of file mtk_interp_1d.cc.

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

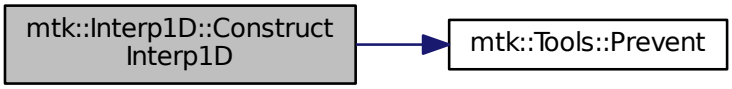
Returns

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:



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

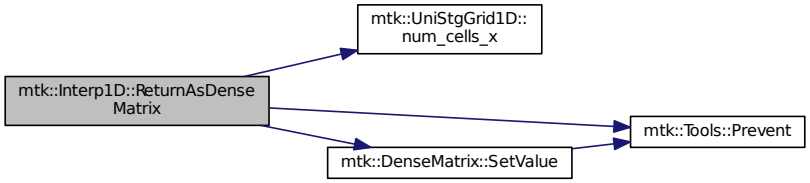
Returns

The operator as a dense matrix.

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

Definition at line 137 of file mtk_interp_1d.cc.

Here is the call graph for this function:



17.11.4 Friends And Related Function Documentation

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

1. Print approximating coefficients for the interior.

Definition at line 66 of file mtk_interp_1d.cc.

17.11.5 Member Data Documentation

17.11.5.1 Real* mtk::Interp1D::coeffs_interior_ [private]

Definition at line 127 of file mtk_interp_1d.h.

17.11.5.2 DirInterp mtk::Interp1D::dir_interp_ [private]

Definition at line 123 of file mtk_interp_1d.h.

17.11.5.3 int mtk::Interp1D::order_accuracy_ [private]

Definition at line 125 of file mtk_interp_1d.h.

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

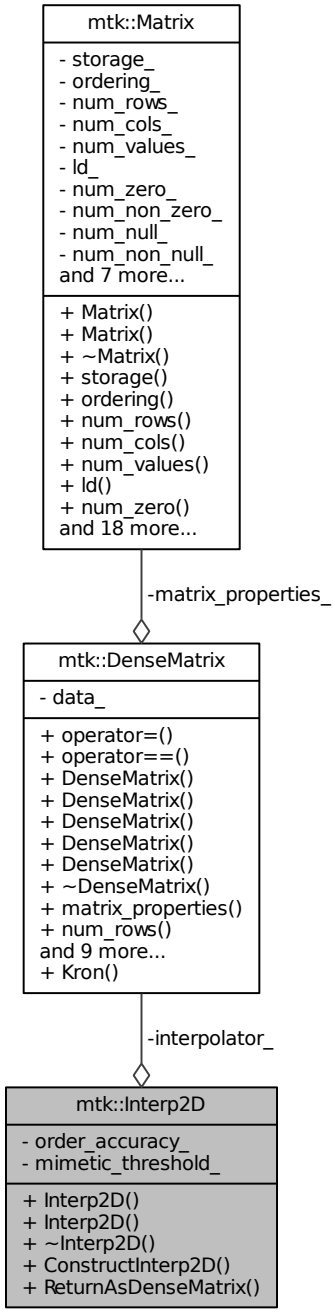
- include/mtk_interp_1d.h
- src/mtk_interp_1d.cc

17.12 mtk::Interp2D Class Reference

Implements a 2D interpolation operator.

`#include <mtk_interp_2d.h>`

Collaboration diagram for mtk::Interp2D:



Public Member Functions

- Interp2D ()

Default constructor.

- Interp2D (const Interp2D &interp)

  Copy constructor.

- ~Interp2D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix ()

  Return the operator as a dense matrix.

Private Attributes

- DenseMatrix interpolator_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.12.1 Detailed Description

This class implements a 2D interpolation operator.

Definition at line 76 of file mtk_interp_2d.h.

17.12.2 Constructor & Destructor Documentation

17.12.2.1 mtk::Interp2D::Interp2D ( )

17.12.2.2 mtk::Interp2D::Interp2D (const Interp2D & *interp*)

Parameters

in	*lap*	Given Laplacian.

17.12.2.3 mtk::Interp2D::~Interp2D ( )

17.12.3 Member Function Documentation

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

Returns

Success of the construction.

17.12.3.2 DenseMatrix mtk::Interp2D::ReturnAsDenseMatrix ( )

Returns

The operator as a dense matrix.

17.12.4 Member Data Documentation

17.12.4.1 DenseMatrix mtk::Interp2D::interpolator_ [private]

Definition at line 108 of file mtk_interp_2d.h.

17.12.4.2 Real mtk::Interp2D::mimetic_threshold_ [private]

Definition at line 112 of file mtk_interp_2d.h.

17.12.4.3 int mtk::Interp2D::order_accuracy_ [private]

Definition at line 110 of file mtk_interp_2d.h.

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

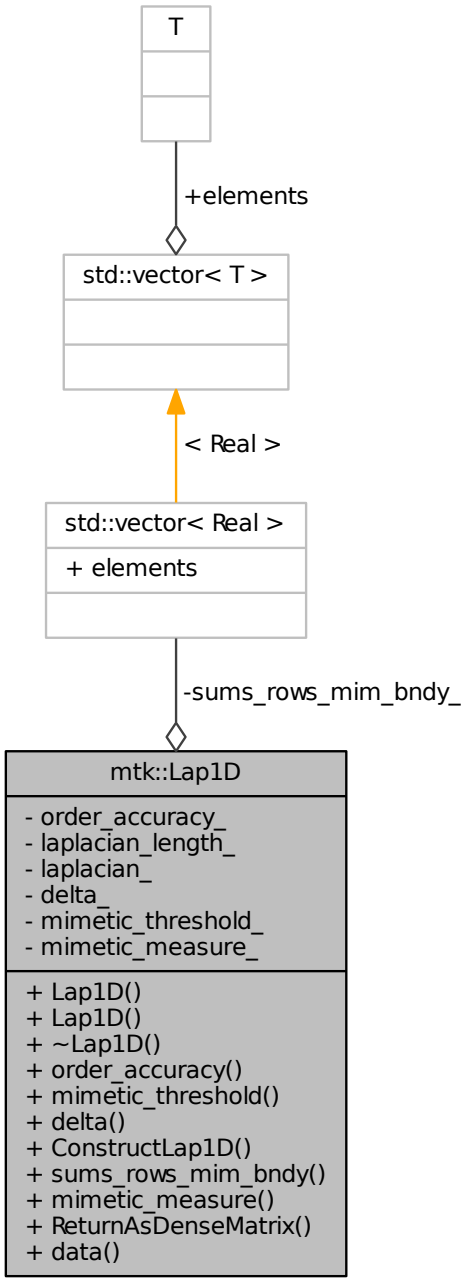
- include/mtk_interp_2d.h

17.13 mtk::Lap1D Class Reference

Implements a 1D mimetic Laplacian operator.

`#include <mtk_lap_1d.h>`

Collaboration diagram for mtk::Lap1D:



Public Member Functions

- Lap1D ()

Default constructor.

- Lap1D (const Lap1D &lap)

  Copy constructor.

- ~Lap1D ()

  Destructor.

- int order_accuracy () const

  Order of accuracy of the operator.

- Real mimetic_threshold () const

  Mimetic threshold used in the CBS algorithm to construct this operator.

- Real delta () const

  Value of Δx used be scaled. If 0, then dimensionless.

- bool ConstructLap1D (int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimetic↩ Threshold)

  Factory method implementing the CBS Algorithm to build operator.

- std::vector< Real > sums_rows_mim_bndy () const

  Return collection of row-sums mimetic approximations at the boundary.

- Real mimetic_measure () const

  Returns mimetic measure of the operator.

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid) const

  Return the operator as a dense matrix.

- const mtk::Real * data (const UniStgGrid1D &grid) const

  Return the operator as a dense array.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.

- int laplacian_length_

  Length of the output array.

- Real * laplacian_

  Output array containing the operator and weights.

- Real delta_

  < If 0.0, then this Laplacian is dimensionless.

- Real mimetic_threshold_

  < Mimetic threshold.

- Real mimetic_measure_

  < Mimetic measure.

- std::vector< Real > sums_rows_mim_bndy_

  Sum of each mimetic boundary row.

Friends

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

  Output stream operator for printing.

17.13.1 Detailed Description

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

Definition at line 78 of file mtk_lap_1d.h.

17.13.2 Constructor & Destructor Documentation

17.13.2.1 mtk::Lap1D::Lap1D ( )

Definition at line 114 of file mtk_lap_1d.cc.

17.13.2.2 mtk::Lap1D::Lap1D (const Lap1D & *lap*)

Parameters

in	*lap*	Given Laplacian.

Definition at line 122 of file mtk_lap_1d.cc.

17.13.2.3 mtk::Lap1D::~Lap1D ( )

Definition at line 130 of file mtk_lap_1d.cc.

17.13.3 Member Function Documentation

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

Returns

Success of the solution.

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

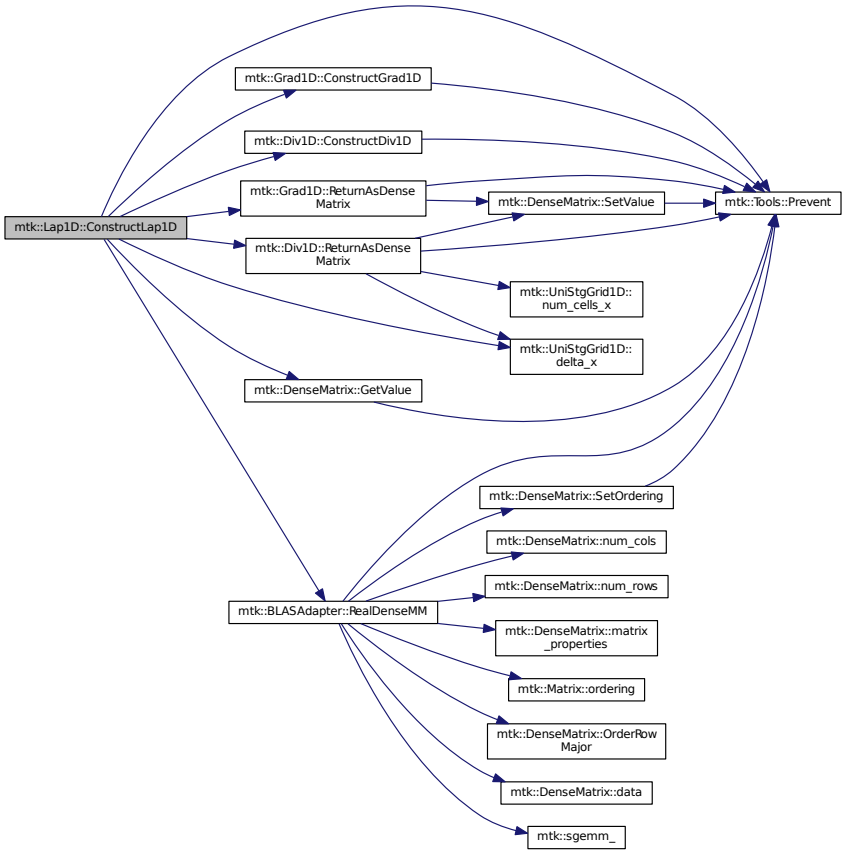
Warning

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

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

Definition at line 151 of file mtk_lap_1d.cc.

Here is the call graph for this function:



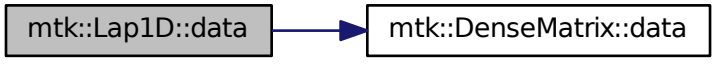
17.13.3.2 const mtk::Real * mtk::Lap1D::data (const UniStgGrid1D & *grid*) const

Returns

The operator as a dense array.

Definition at line 387 of file mtk_lap_1d.cc.

Here is the call graph for this function:



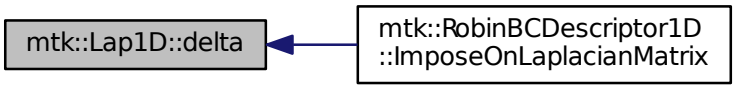
17.13.3.3 mtk::Real mtk::Lap1D::delta ( ) const

Returns

Value of Δx used be scaled. If 0, then dimensionless.

Definition at line 146 of file mtk_lap_1d.cc.

Here is the caller graph for this function:



17.13.3.4 mtk::Real mtk::Lap1D::mimetic_measure ( ) const

Returns

Real number which is the mimetic measure of the operator.

Definition at line 312 of file mtk_lap_1d.cc.

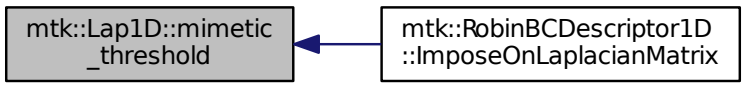
17.13.3.5 mtk::Real mtk::Lap1D::mimetic_threshold ( ) const

Returns

Mimetic threshold used in the CBS algorithm to construct operator.

Definition at line 141 of file mtk_lap_1d.cc.

Here is the caller graph for this function:



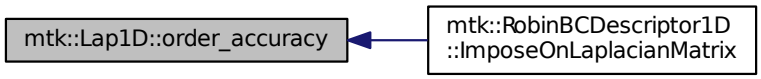
17.13.3.6 int mtk::Lap1D::order_accuracy ( ) const

Returns

Order of accuracy of the operator.

Definition at line 136 of file mtk_lap_1d.cc.

Here is the caller graph for this function:



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

Returns

The operator as a dense matrix.

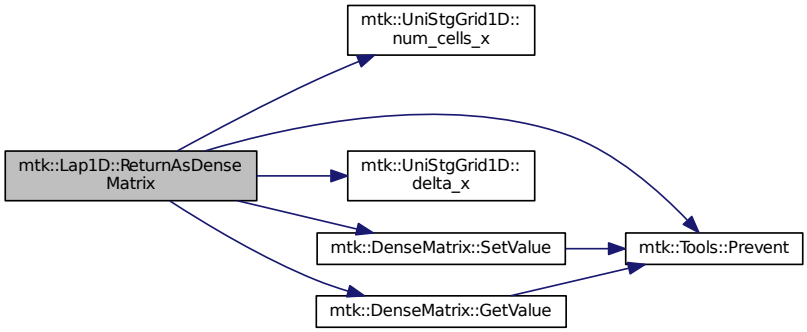
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

Note

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

Definition at line 317 of file mtk_lap_1d.cc.

Here is the call graph for this function:



17.13.3.8 std::vector< mtk::Real > mtk::Lap1D::sums_rows_mim_bndy ( ) const

Returns

Collection of row-sums mimetic approximations at the boundary.

Definition at line 307 of file mtk_lap_1d.cc.

17.13.4 Friends And Related Function Documentation

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

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

Definition at line 75 of file mtk_lap_1d.cc.

17.13.5 Member Data Documentation

17.13.5.1 Real mtk::Lap1D::delta_ [mutable], [private]

Definition at line 159 of file mtk_lap_1d.h.

17.13.5.2 Real* mtk::Lap1D::laplacian_ [private]

Definition at line 157 of file mtk_lap_1d.h.

17.13.5.3 int mtk::Lap1D::laplacian_length_ [private]

Definition at line 155 of file mtk_lap_1d.h.

17.13.5.4 Real mtk::Lap1D::mimetic_measure_ [private]

Definition at line 162 of file mtk_lap_1d.h.

17.13.5.5 Real mtk::Lap1D::mimetic_threshold_ [private]

Definition at line 161 of file mtk_lap_1d.h.

17.13.5.6 int mtk::Lap1D::order_accuracy_ [private]

Definition at line 154 of file mtk_lap_1d.h.

17.13.5.7 std::vector<Real> mtk::Lap1D::sums_rows_mim_bndy_ [private]

Definition at line 164 of file mtk_lap_1d.h.

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

- include/mtk_lap_1d.h

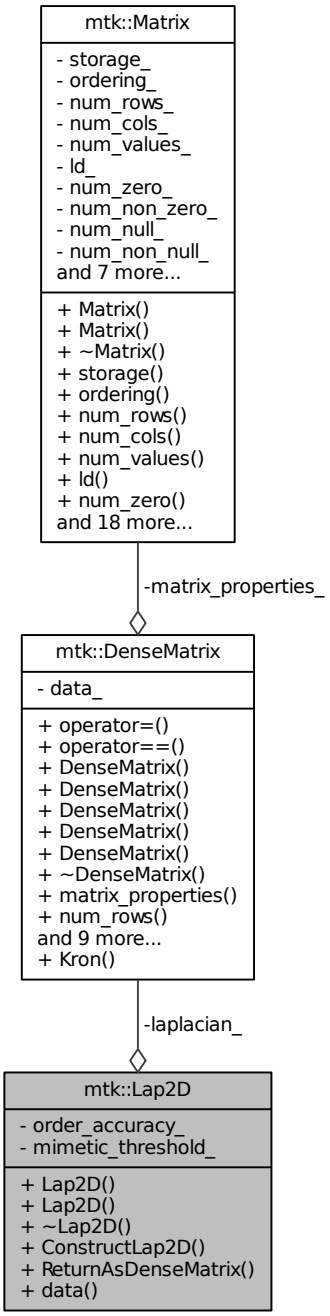
- src/mtk_lap_1d.cc

17.14 mtk::Lap2D Class Reference

Implements a 2D mimetic Laplacian operator.

`#include <mtk_lap_2d.h>`

Collaboration diagram for mtk::Lap2D:



Public Member Functions

- Lap2D ()

Default constructor.

- Lap2D (const Lap2D &lap)

  Copy constructor.

- ~Lap2D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

- Real * data () const

  Return the operator as a dense array.

Private Attributes

- DenseMatrix laplacian_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.14.1 Detailed Description

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

Definition at line 76 of file mtk_lap_2d.h.

17.14.2 Constructor & Destructor Documentation

17.14.2.1 mtk::Lap2D::Lap2D ( )

Definition at line 69 of file mtk_lap_2d.cc.

17.14.2.2 mtk::Lap2D::Lap2D (const Lap2D & *lap*)

Parameters

in	*lap*	Given Laplacian.

Definition at line 71 of file mtk_lap_2d.cc.

17.14.2.3 mtk::Lap2D::~Lap2D ( )

Definition at line 75 of file mtk_lap_2d.cc.

17.14.3 Member Function Documentation

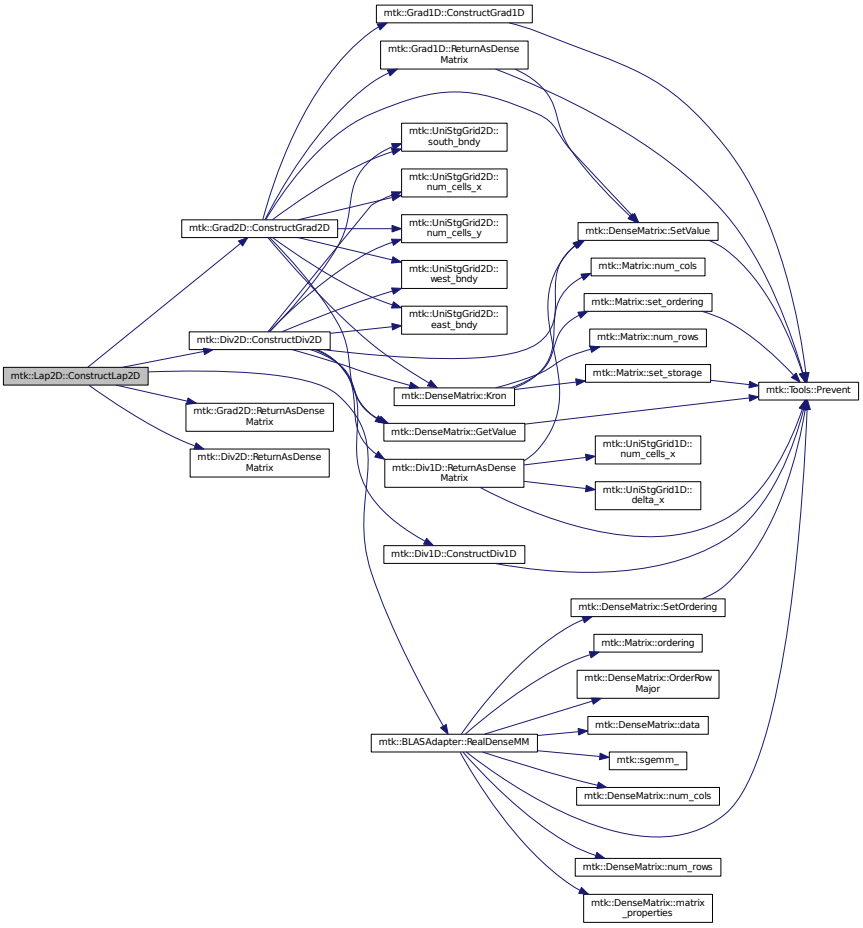
17.14.3.1 bool mtk::Lap2D::ConstructLap2D (const UniStgGrid2D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 77 of file mtk_lap_2d.cc.

Here is the call graph for this function:



17.14.3.2 mtk::Real * mtk::Lap2D::data ( ) const

Returns

The operator as a dense array.

Definition at line 115 of file mtk_lap_2d.cc.

17.14.3.3 DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 110 of file mtk_lap_2d.cc.

17.14.4 Member Data Documentation

17.14.4.1 DenseMatrix mtk::Lap2D::laplacian_ [private]

Definition at line 115 of file mtk_lap_2d.h.

17.14.4.2 Real mtk::Lap2D::mimetic_threshold_ [private]

Definition at line 119 of file mtk_lap_2d.h.

17.14.4.3 int mtk::Lap2D::order_accuracy_ [private]

Definition at line 117 of file mtk_lap_2d.h.

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

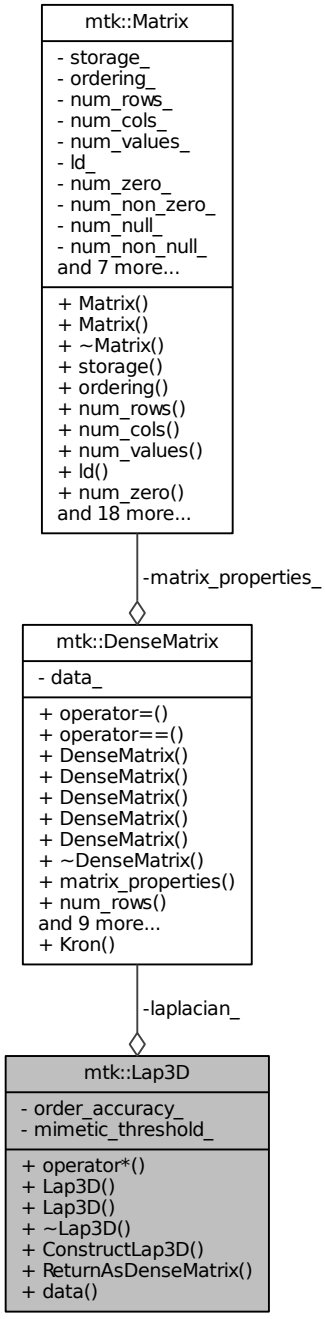
- include/mtk_lap_2d.h
- src/mtk_lap_2d.cc

17.15 mtk::Lap3D Class Reference

Implements a 3D mimetic Laplacian operator.

`#include <mtk_lap_3d.h>`

Collaboration diagram for mtk::Lap3D:



Public Member Functions

- UniStgGrid3D operator∗ (const UniStgGrid3D &grid) const

Operator application operator on a grid.

- Lap3D ()

  Default constructor.

- Lap3D (const Lap3D &lap)

  Copy constructor.

- ~Lap3D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- DenseMatrix ReturnAsDenseMatrix () const

  Return the operator as a dense matrix.

- Real * data () const

  Return the operator as a dense array.

Private Attributes

- DenseMatrix laplacian_

  Actual operator.

- int order_accuracy_

  Order of accuracy.

- Real mimetic_threshold_

  Mimetic Threshold.

17.15.1 Detailed Description

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

Definition at line 76 of file mtk_lap_3d.h.

17.15.2 Constructor & Destructor Documentation

17.15.2.1 mtk::Lap3D::Lap3D ( )

Definition at line 76 of file mtk_lap_3d.cc.

17.15.2.2 mtk::Lap3D::Lap3D (const Lap3D & *lap*)

Parameters

in	*lap*	Given Laplacian.

Definition at line 78 of file mtk_lap_3d.cc.

17.15.2.3 mtk::Lap3D::~Lap3D ( )

Definition at line 82 of file mtk_lap_3d.cc.

17.15.3 Member Function Documentation

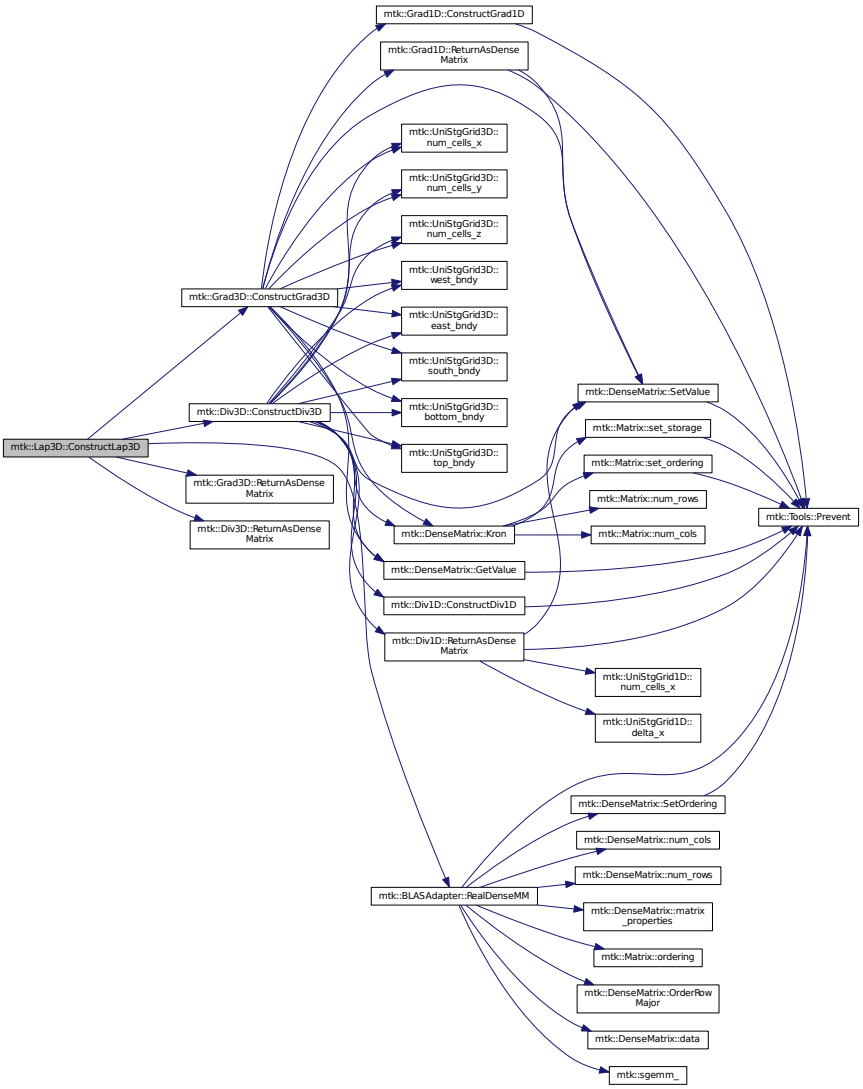
17.15.3.1 bool mtk::Lap3D::ConstructLap3D (const UniStgGrid3D & *grid*, int *order_accuracy* = kDefaultOrderAccuracy, mtk::Real *mimetic_threshold* = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 84 of file mtk_lap_3d.cc.

Here is the call graph for this function:



17.15.3.2 mtk::Real * mtk::Lap3D::data ( ) const

Returns

The operator as a dense array.

Definition at line 122 of file mtk_lap_3d.cc.

17.15.3.3 mtk::UniStgGrid3D mtk::Lap3D::operator∗ (const UniStgGrid3D & *grid*) const

Definition at line 69 of file mtk_lap_3d.cc.

17.15.3.4 mtk::DenseMatrix mtk::Lap3D::ReturnAsDenseMatrix ( ) const

Returns

The operator as a dense matrix.

Definition at line 117 of file mtk_lap_3d.cc.

17.15.4 Member Data Documentation

17.15.4.1 DenseMatrix mtk::Lap3D::laplacian_ [private]

Definition at line 118 of file mtk_lap_3d.h.

17.15.4.2 Real mtk::Lap3D::mimetic_threshold_ [private]

Definition at line 122 of file mtk_lap_3d.h.

17.15.4.3 int mtk::Lap3D::order_accuracy_ [private]

Definition at line 120 of file mtk_lap_3d.h.

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

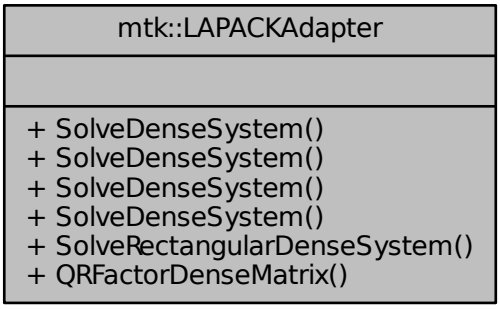
- include/mtk_lap_3d.h
- src/mtk_lap_3d.cc

17.16 mtk::LAPACKAdapter Class Reference

Adapter class for the LAPACK API.

`#include <mtk_lapack_adapter.h>`

Collaboration diagram for mtk::LAPACKAdapter:



Static Public Member Functions

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

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

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

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

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

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

  Performs a QR factorization on a dense matrix.

17.16.1 Detailed Description

This class contains a collection of static member functions, 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 94 of file mtk_lapack_adapter.h.

17.16.2 Member Function Documentation

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

Adapts the MTK to LAPACK's routine.

Parameters

in,out	*matrix*	Input matrix.

Returns

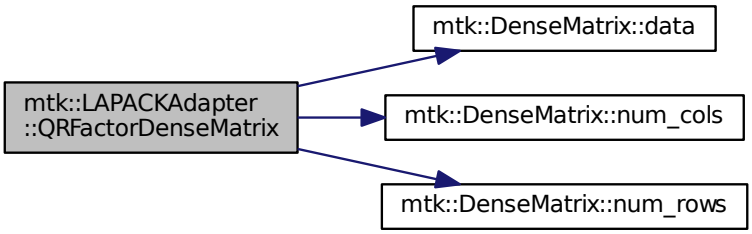
Matrix $\mathbf{Q}$.

Exceptions

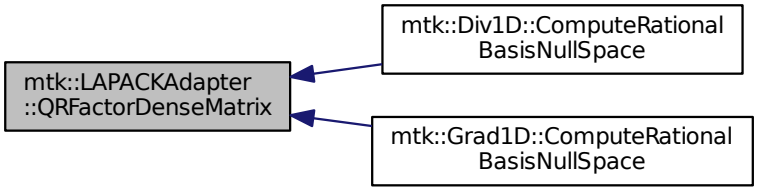
std::bad_alloc	

Definition at line 594 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

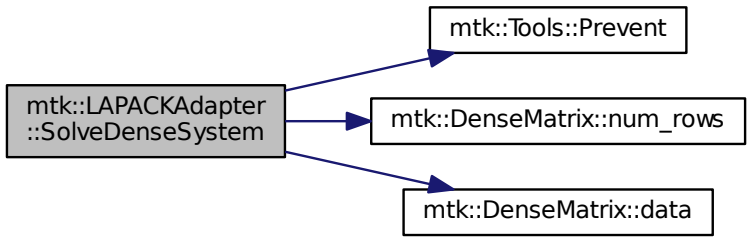
in	*matrix*	Input matrix.
in	*rhs*	Input right-hand sides vector.

Exceptions

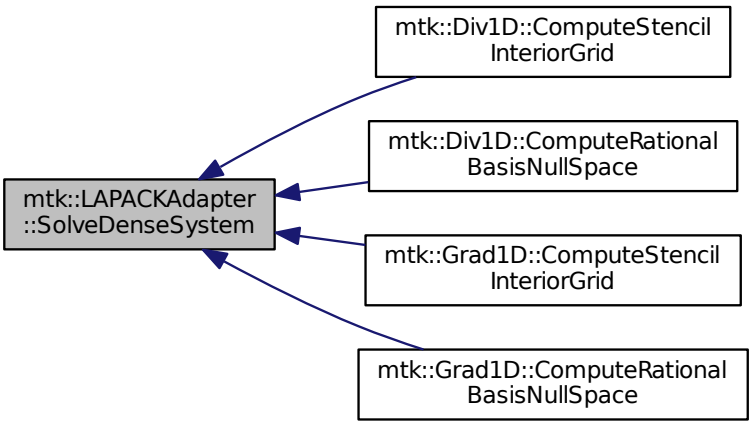
std::bad_alloc	

Definition at line 431 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

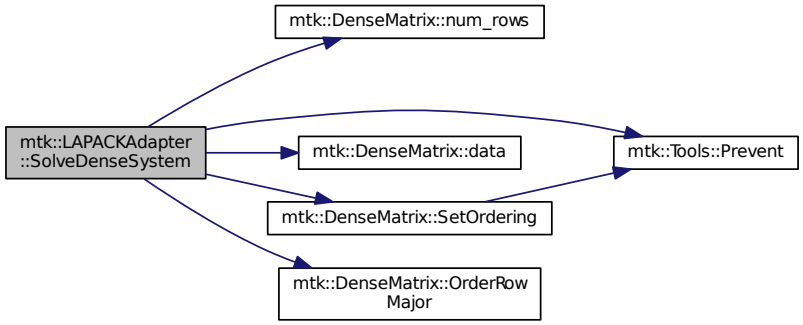
in	*matrix*	Input matrix.
in	*rr*	Input right-hand sides matrix.

Exceptions

std::bad_alloc	

Definition at line 466 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

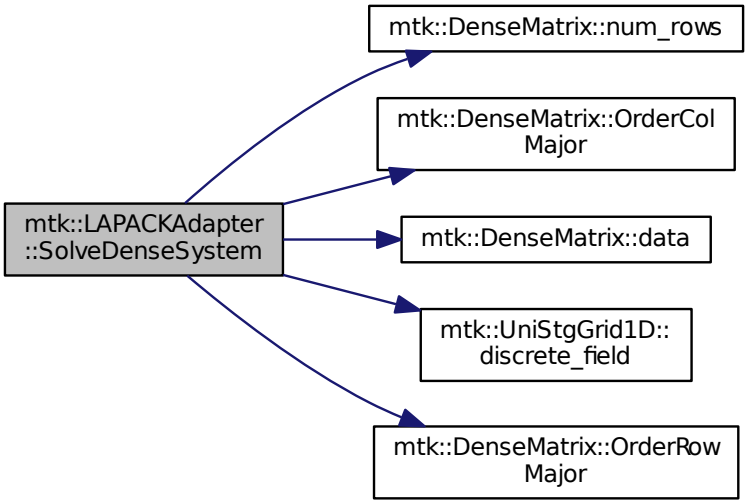
in	*matrix*	Input matrix.
in	*rhs*	Input right-hand side from info on a grid.

Exceptions

std::bad_alloc	

Definition at line 518 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

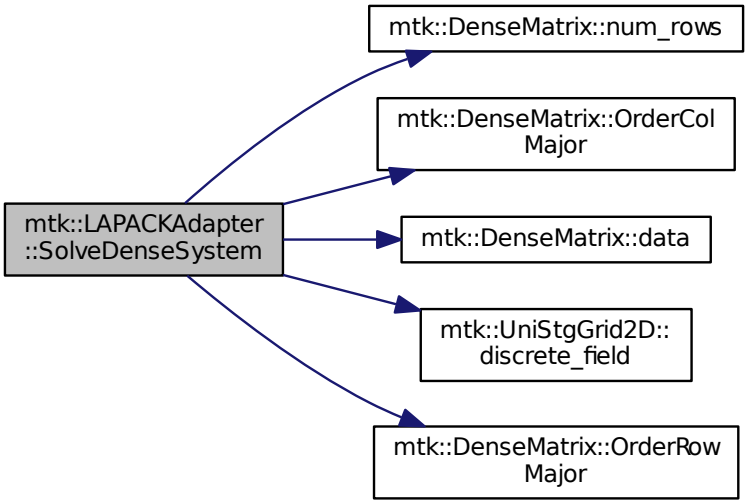
in	*matrix*	Input matrix.
in	*rhs*	Input right-hand side from info on a grid.

Exceptions

std::bad_alloc	

Definition at line 556 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



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

Adapts the MTK to LAPACK's routine.

Parameters

in,out	*matrix*	Input matrix.

Returns

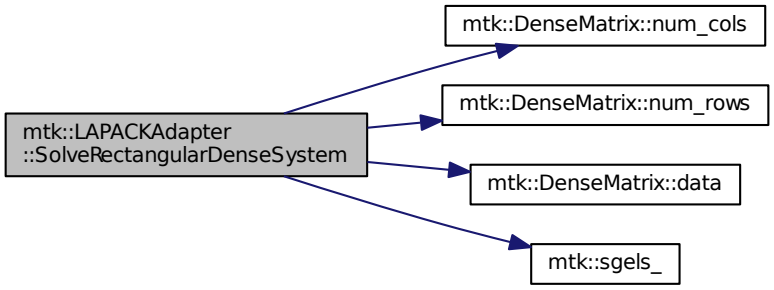
Success of the solution.

Exceptions

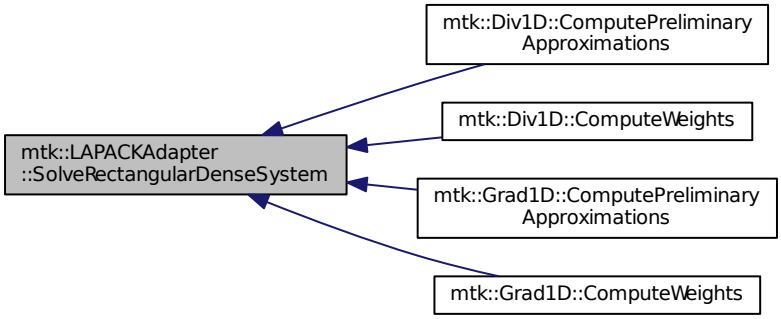
std::bad_alloc	

Definition at line 791 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:

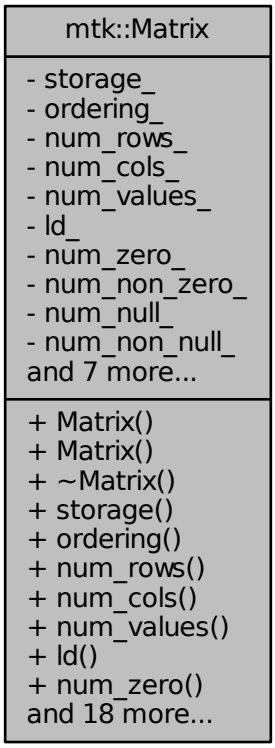
- include/mtk_lapack_adapter.h
- src/mtk_lapack_adapter.cc

17.17 mtk::Matrix Class Reference

Definition of the representation of a matrix in the MTK.

`#include <mtk_matrix.h>`

Collaboration diagram for mtk::Matrix:



Public Member Functions

- Matrix ()

  Default constructor.
- Matrix (const Matrix &in)

  Copy constructor.
- ~Matrix () noexcept

  Destructor.
- MatrixStorage storage () const noexcept

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

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

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

  Gets the number of rows.

- int num_values () const noexcept

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

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

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

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

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

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

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

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

  Gets the bandwidth.
- Real abs_density () const noexcept

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

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

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

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

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

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

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

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

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

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

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

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

Private Attributes

- MatrixStorage storage_
  What type of matrix is this?
- MatrixOrdering ordering_
  What kind of ordering is it following?
- int num_rows_
  Number of rows.
- int num_cols_
  Number of columns.
- int num_values_
  Number of total values in matrix.
- int ld_
  Elements between successive rows when row-major.
- int num_zero_
  Number of zeros.
- int num_non_zero_
  Number of non-zero values.
- int num_null_
  Number of null (insignificant) values.
- int num_non_null_
  Number of null (significant) values.
- int kl_
  Number of lower diagonals on a banded matrix.
- int ku_
  Number of upper diagonals on a banded matrix.
- int bandwidth_
  Bandwidth of the matrix.
- Real abs_density_
  Absolute density of matrix.
- Real rel_density_
  Relative density of matrix.
- Real abs_sparsity_
  Absolute sparsity of matrix.
- Real rel_sparsity_
  Relative sparsity of matrix.

17.17.1 Detailed Description

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

Definition at line 75 of file mtk_matrix.h.

17.17.2 Constructor & Destructor Documentation

17.17.2.1 mtk::Matrix::Matrix ( )

Definition at line 67 of file mtk_matrix.cc.

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

Parameters

in	*in*	Given matrix.

Definition at line 86 of file mtk_matrix.cc.

17.17.2.3 mtk::Matrix::~Matrix ( ) [noexcept]

Definition at line 105 of file mtk_matrix.cc.

17.17.3 Member Function Documentation

17.17.3.1 Real mtk::Matrix::abs_density ( ) const [noexcept]

See also

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

Returns

Absolute density of the matrix.

17.17.3.2 mtk::Real mtk::Matrix::abs_sparsity ( ) const [noexcept]

See also

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

Returns

Absolute sparsity of the matrix.

Definition at line 177 of file mtk_matrix.cc.

17.17.3.3 int mtk::Matrix::bandwidth ( ) const [noexcept]

Returns

Bandwidth of the matrix.

Definition at line 167 of file mtk_matrix.cc.

17.17.3.4 void mtk::Matrix::IncreaseNumNull ( ) [noexcept]

Todo Review the definition of sparse matrices properties.

Definition at line 275 of file mtk_matrix.cc.

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

Todo Review the definition of sparse matrices properties.

Definition at line 265 of file mtk_matrix.cc.

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

Returns

Number of lower diagonals.

Definition at line 157 of file mtk_matrix.cc.

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

Returns

Number of upper diagonals.

Definition at line 162 of file mtk_matrix.cc.

17.17.3.8 int mtk::Matrix::ld ( ) const [noexcept]

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

Returns

Leading dimension of the matrix.

Definition at line 132 of file mtk_matrix.cc.

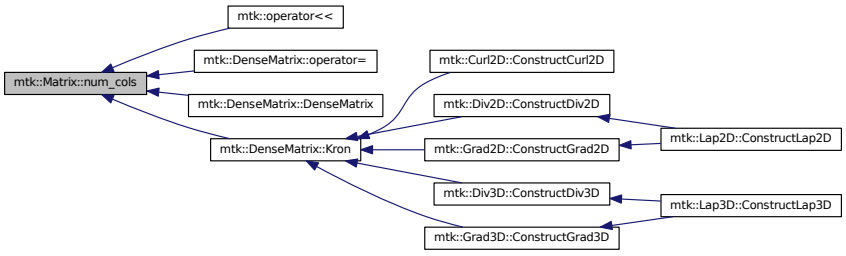
17.17.3.9 int mtk::Matrix::num_cols ( ) const [noexcept]

Returns

Number of rows of the matrix.

Definition at line 122 of file mtk_matrix.cc.

Here is the caller graph for this function:



17.17.3.10 int mtk::Matrix::num_non_null ( ) const [noexcept]

See also

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

Returns

Number of non-null values of the matrix.

Definition at line 152 of file mtk_matrix.cc.

17.17.3.11 int mtk::Matrix::num_non_zero ( ) const [noexcept]

Returns

Number of non-zero values of the matrix.

Definition at line 142 of file mtk_matrix.cc.

17.17.3.12 int mtk::Matrix::num_null ( ) const [noexcept]

See also

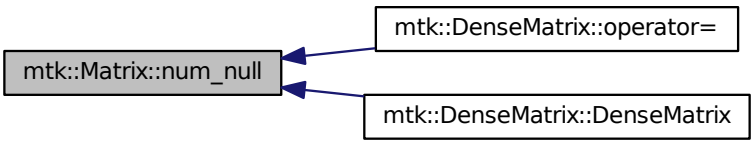
http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

Returns

Number of null values of the matrix.

Definition at line 147 of file mtk_matrix.cc.

Here is the caller graph for this function:



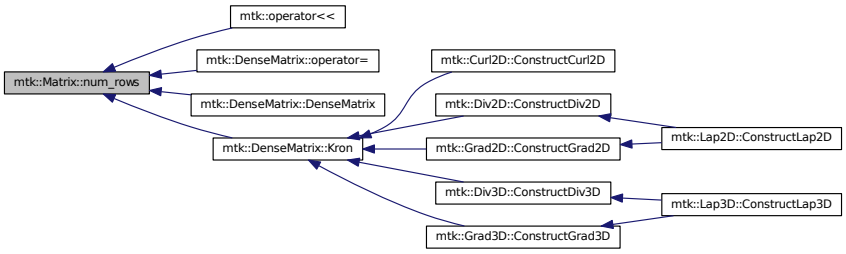
17.17.3.13 int mtk::Matrix::num_rows ( ) const [noexcept]

Returns

Number of rows of the matrix.

Definition at line 117 of file mtk_matrix.cc.

Here is the caller graph for this function:



17.17.3.14 int mtk::Matrix::num_values ( ) const [noexcept]

Returns

Number of values of the matrix.

Definition at line 127 of file mtk_matrix.cc.

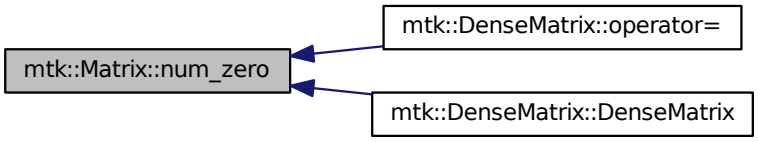
17.17.3.15 int mtk::Matrix::num_zero ( ) const [noexcept]

Returns

Number of zeros of the matrix.

Definition at line 137 of file mtk_matrix.cc.

Here is the caller graph for this function:



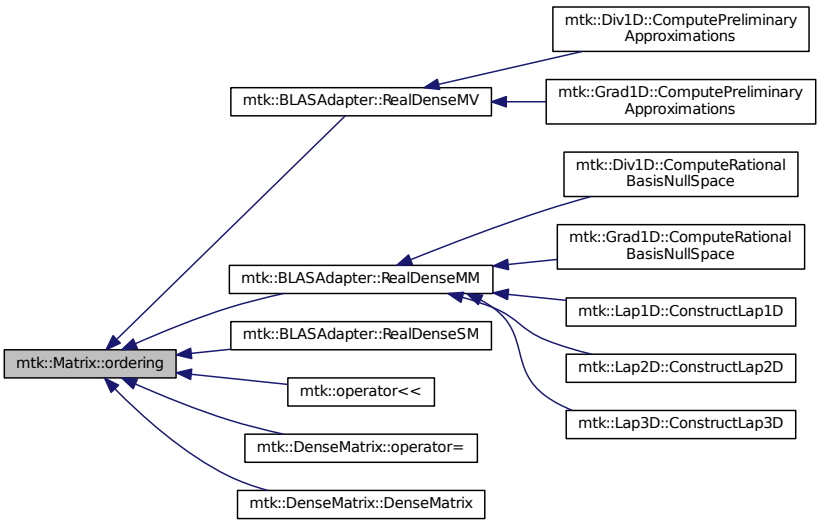
17.17.3.16 mtk::MatrixOrdering mtk::Matrix::ordering ( ) const [noexcept]

Returns

Type of ordering of this matrix.

Definition at line 112 of file mtk_matrix.cc.

Here is the caller graph for this function:



17.17.3.17 mtk::Real mtk::Matrix::rel_density ( ) const [noexcept]

See also

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

Returns

Relative density of the matrix.

Definition at line 172 of file mtk_matrix.cc.

17.17.3.18 mtk::Real mtk::Matrix::rel_sparsity ( ) const [noexcept]

See also

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

Returns

Relative sparsity of the matrix.

Definition at line 182 of file mtk_matrix.cc.

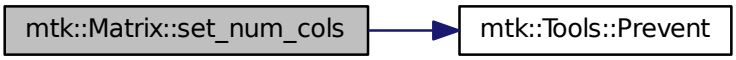
17.17.3.19 void mtk::Matrix::set_num_cols (const int & *num_cols*) [noexcept]

Parameters

in	*num_cols*	Number of columns.

Definition at line 225 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

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

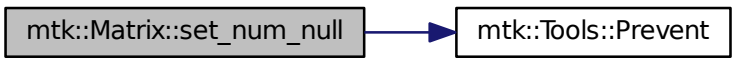
Parameters

in	*in*	Number of zero values.

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

Definition at line 251 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

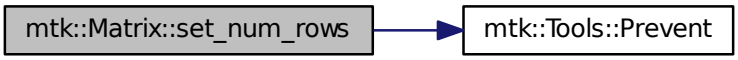
17.17.3.21 void mtk::Matrix::set_num_rows (const int & *num_rows*) [noexcept]

Parameters

in	*num_rows*	Number of rows.

Definition at line 213 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

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

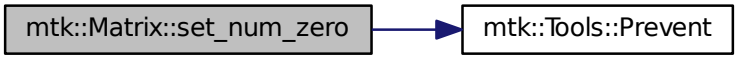
Parameters

in	*in*	Number of zero values.

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

Definition at line 237 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

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

See also

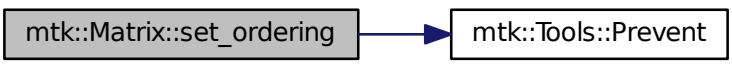
MatrixOrdering

Parameters

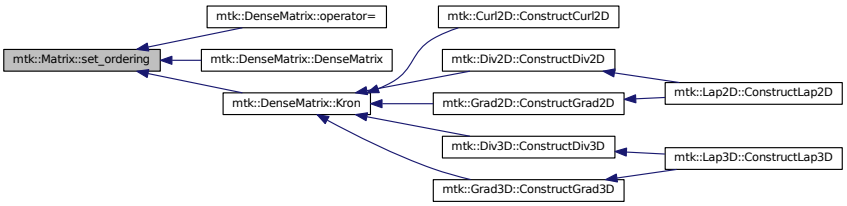
in	*oo*	Ordering of the matrix.

Definition at line 199 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

See also

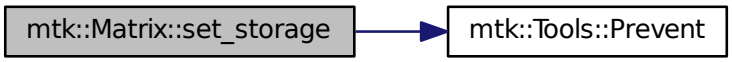
MatrixStorage

Parameters

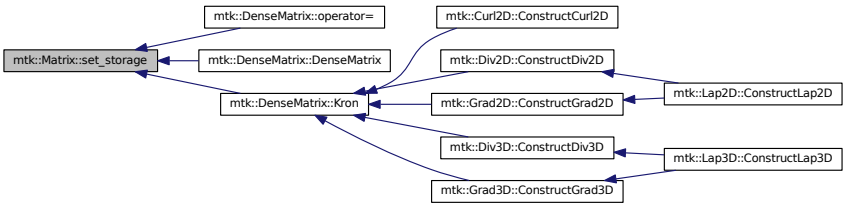
in	*tt*	Type of the matrix storage.

Definition at line 187 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



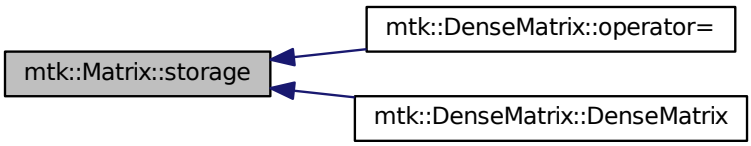
17.17.3.25 mtk::MatrixStorage mtk::Matrix::storage ( ) const [noexcept]

Returns

Type of storage of this matrix.

Definition at line 107 of file mtk_matrix.cc.

Here is the caller graph for this function:



17.17.4 Member Data Documentation

17.17.4.1 Real mtk::Matrix::abs_density_ [private]

Definition at line 296 of file mtk_matrix.h.

17.17.4.2 Real mtk::Matrix::abs_sparsity_ [private]

Definition at line 298 of file mtk_matrix.h.

17.17.4.3 int mtk::Matrix::bandwidth_ [private]

Definition at line 294 of file mtk_matrix.h.

17.17.4.4 int mtk::Matrix::kl_ [private]

Definition at line 292 of file mtk_matrix.h.

17.17.4.5 int mtk::Matrix::ku_ [private]

Definition at line 293 of file mtk_matrix.h.

17.17.4.6 int mtk::Matrix::ld_ [private]

Definition at line 285 of file mtk_matrix.h.

17.17.4.7 int mtk::Matrix::num_cols_ [private]

Definition at line 283 of file mtk_matrix.h.

17.17.4.8 int mtk::Matrix::num_non_null_ [private]

Definition at line 290 of file mtk_matrix.h.

17.17.4.9 int mtk::Matrix::num_non_zero_ [private]

Definition at line 288 of file mtk_matrix.h.

17.17.4.10 int mtk::Matrix::num_null_ [private]

Definition at line 289 of file mtk_matrix.h.

17.17.4.11 int mtk::Matrix::num_rows_ [private]

Definition at line 282 of file mtk_matrix.h.

17.17.4.12 int mtk::Matrix::num_values_ [private]

Definition at line 284 of file mtk_matrix.h.

17.17.4.13 int mtk::Matrix::num_zero_ [private]

Definition at line 287 of file mtk_matrix.h.

17.17.4.14 MatrixOrdering mtk::Matrix::ordering_ [private]

Definition at line 280 of file mtk_matrix.h.

17.17.4.15 Real mtk::Matrix::rel_density_ [private]

Definition at line 297 of file mtk_matrix.h.

17.17.4.16 Real mtk::Matrix::rel_sparsity_ [private]

Definition at line 299 of file mtk_matrix.h.

17.17.4.17 MatrixStorage mtk::Matrix::storage_ [private]

Definition at line 278 of file mtk_matrix.h.

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

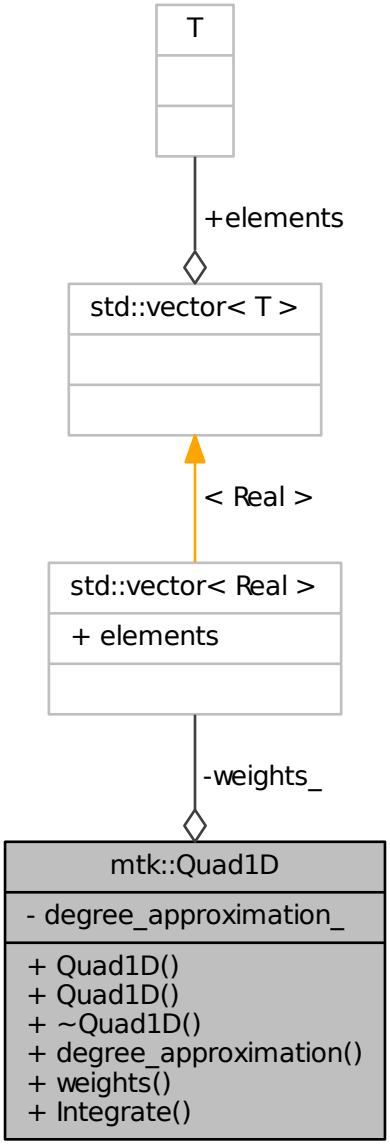
- include/mtk_matrix.h
- src/mtk_matrix.cc

17.18 mtk::Quad1D Class Reference

Implements a 1D mimetic quadrature.

`#include <mtk_quad_1d.h>`

Collaboration diagram for mtk::Quad1D:



Public Member Functions

- Quad1D ()

  Default constructor.
- Quad1D (const Quad1D &quad)

  Copy constructor.
- ~Quad1D ()

  Destructor.
- int degree_approximation () const

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

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

  Mimetic integration routine.

Private Attributes

- int degree_approximation_

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

  Collection of weights.

Friends

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

  Output stream operator for printing.

17.18.1 Detailed Description

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

Definition at line 81 of file mtk_quad_1d.h.

17.18.2 Constructor & Destructor Documentation

17.18.2.1 mtk::Quad1D::Quad1D ( )

17.18.2.2 mtk::Quad1D::Quad1D (const Quad1D & *quad*)

Parameters

in	*div*	Given quadrature.

17.18.2.3 mtk::Quad1D::~Quad1D ( )

17.18.3 Member Function Documentation

17.18.3.1 int mtk::Quad1D::degree_approximation ( ) const

Returns

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

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

Parameters

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

Returns

Result of the integration.

17.18.3.3 Real* mtk::Quad1D::weights ( ) const

Returns

Collection of weights.

17.18.4 Friends And Related Function Documentation

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

17.18.5 Member Data Documentation

17.18.5.1 int mtk::Quad1D::degree_approximation_ [private]

Definition at line 124 of file mtk_quad_1d.h.

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

Definition at line 126 of file mtk_quad_1d.h.

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

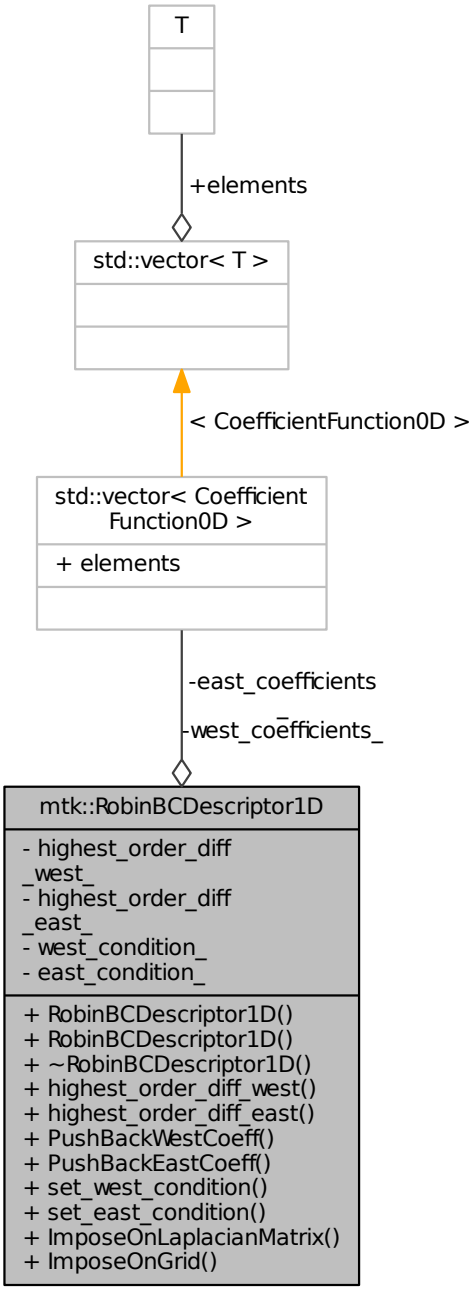
- include/mtk_quad_1d.h

17.19 mtk::RobinBCDescriptor1D Class Reference

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

`#include <mtk_robin_bc_descriptor_1d.h>`

Collaboration diagram for mtk::RobinBCDescriptor1D:



Public Member Functions

- RobinBCDescriptor1D ()

Default constructor.

- RobinBCDescriptor1D (const RobinBCDescriptor1D &desc)

  Copy constructor.
- ~RobinBCDescriptor1D () noexcept

  Destructor.
- int highest_order_diff_west () const noexcept

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

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

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

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

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

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

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

  Imposes the condition on the grid.

Private Attributes

- int highest_order_diff_west_

  Highest order of differentiation for west.
- int highest_order_diff_east_

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

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

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

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

  Condition for east.

17.19.1 Detailed Description

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

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

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

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Definition at line 155 of file mtk_robin_bc_descriptor_1d.h.

17.19.2 Constructor & Destructor Documentation

17.19.2.1 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D ( )

Definition at line 93 of file mtk_robin_bc_descriptor_1d.cc.

17.19.2.2 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D (const RobinBCDescriptor1D & *desc*)

Parameters

in	*desc*	Given 1D descriptor.

Definition at line 99 of file mtk_robin_bc_descriptor_1d.cc.

17.19.2.3 mtk::RobinBCDescriptor1D::~RobinBCDescriptor1D ( ) [noexcept]

Definition at line 106 of file mtk_robin_bc_descriptor_1d.cc.

17.19.3 Member Function Documentation

17.19.3.1 int mtk::RobinBCDescriptor1D::highest_order_diff_east ( ) const [noexcept]

Returns

Integer highest order of differentiation in the east boundary.

Definition at line 113 of file mtk_robin_bc_descriptor_1d.cc.

17.19.3.2 int mtk::RobinBCDescriptor1D::highest_order_diff_west ( ) const [noexcept]

Returns

Integer highest order of differentiation in the west boundary.

Definition at line 108 of file mtk_robin_bc_descriptor_1d.cc.

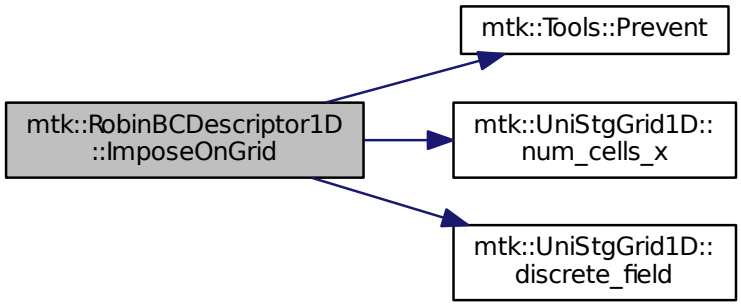
17.19.3.3 void mtk::RobinBCDescriptor1D::ImposeOnGrid (UniStgGrid1D & *grid*, const Real & *time* = mtk::kZero) const

Parameters

in,out	*grid*	Grid upon which impose the desired boundary condition.
in	*time*	Current time snapshot. Default is kZero.

Definition at line 246 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



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

Parameters

in	*lap*	Operator in the Matrix.
in,out	*matrix*	Input Laplacian operator.
in	*time*	Current time snapshot. Default is kZero.

Returns

Success of the imposition.

1. Impose Dirichlet coefficients. 1.1. Impose Dirichlet condition at the west.

1.2. Impose Dirichlet condition at the east.

1. Impose Neumann coefficients.

2.1. Create a mimetic gradient to approximate the first derivative.

2.2. Extract the coefficients approximating the boundary.

Warning

Coefficients returned by the mim_bndy getter are dimensionless! Therefore we must scale them by delta_x (from the grid), before adding to the matrix! But this information is in the given lap!

2.3. Impose Neumann condition at the west.

2.3.1. Get gradient coefficient and scale it.

2.3.2. Multiply times the coefficient for this boundary, times the unit normal for this boundary.

2.3.3. Set the final value summing it with what is on the matrix.

2.4. Impose Neumann condition at the east.

Warning

The Coefficients returned by the mim_bndy getter are those intended for the west boundary. We must enforce the center-skew-symmetry of the resulting operator by permuting their location in the matrix, and changing their sign.

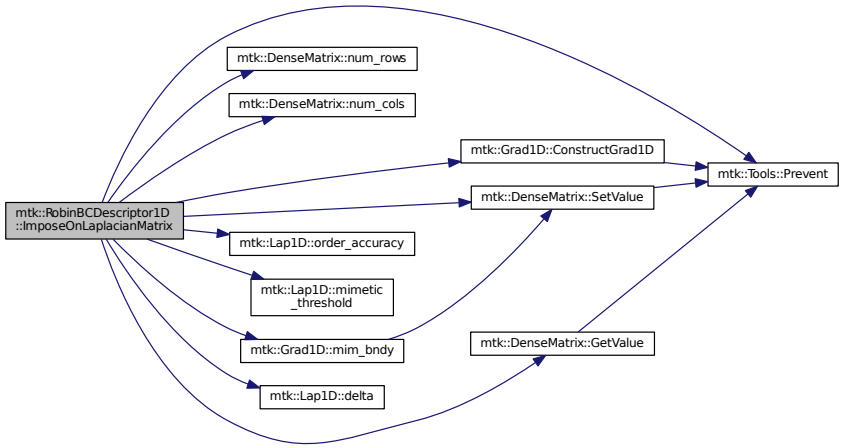
2.4.1. Get gradient coefficient and scale it.

2.4.2. Multiply times the coefficient for this boundary, times the unit normal for this boundary, and change the sign to enforce center-skew-symmetry.

2.4.3. Set the final value summing it with what is on the matrix.

Definition at line 166 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



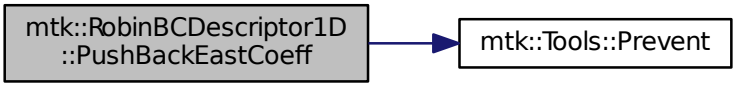
17.19.3.5 void mtk::RobinBCDescriptor1D::PushBackEastCoeff (mtk::CoefficientFunction0D *ce*)

Parameters

in	*ce*	Function $c_e(x,y) : \Omega \mapsto \mathbb{R}$.

Definition at line 132 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



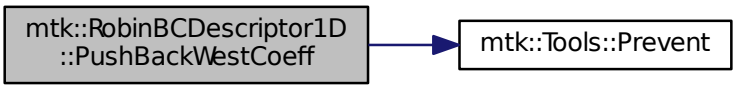
17.19.3.6 void mtk::RobinBCDescriptor1D::PushBackWestCoeff (mtk::CoefficientFunction0D *cw*)

Parameters

in	*cw*	Function $c_w(x,y) : \Omega \mapsto \mathbb{R}$.

Definition at line 118 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



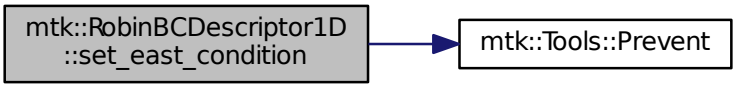
17.19.3.7 void mtk::RobinBCDescriptor1D::set_east_condition (Real(∗)(const Real &tt) *east_condition*) [noexcept]

Parameters

in	*east_condition*	$\beta_e(y,t) : \Omega \mapsto \mathbb{R}$.

Definition at line 156 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



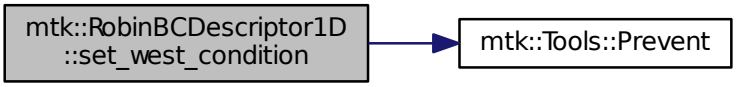
17.19.3.8 void mtk::RobinBCDescriptor1D::set_west_condition (Real(∗)(const Real &tt) *west_condition*) [noexcept]

Parameters

in	*west_condition*	$\beta_w(y,t) : \Omega \mapsto \mathbb{R}$.

Definition at line 146 of file mtk_robin_bc_descriptor_1d.cc.

Here is the call graph for this function:



17.19.4 Member Data Documentation

17.19.4.1 std::vector<CoefficientFunction0D> mtk::RobinBCDescriptor1D::east_coefficients_ [private]

Definition at line 237 of file mtk_robin_bc_descriptor_1d.h.

17.19.4.2 Real(∗ mtk::RobinBCDescriptor1D::east_condition_)(const Real &tt) [private]

Definition at line 240 of file mtk_robin_bc_descriptor_1d.h.

17.19.4.3 int mtk::RobinBCDescriptor1D::highest_order_diff_east_ [private]

Definition at line 234 of file mtk_robin_bc_descriptor_1d.h.

17.19.4.4 int mtk::RobinBCDescriptor1D::highest_order_diff_west_ [private]

Definition at line 233 of file mtk_robin_bc_descriptor_1d.h.

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

Definition at line 236 of file mtk_robin_bc_descriptor_1d.h.

17.19.4.6 Real(* mtk::RobinBCDescriptor1D::west_condition_)(const Real &tt) [private]

Definition at line 239 of file mtk_robin_bc_descriptor_1d.h.

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

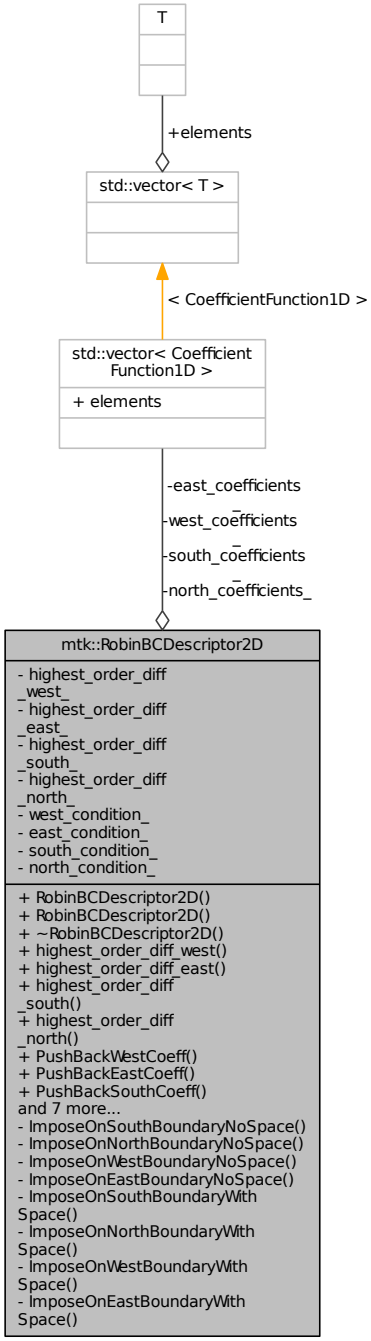
- include/mtk_robin_bc_descriptor_1d.h
- src/mtk_robin_bc_descriptor_1d.cc

17.20 mtk::RobinBCDescriptor2D Class Reference

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

`#include <mtk_robin_bc_descriptor_2d.h>`

Collaboration diagram for mtk::RobinBCDescriptor2D:



Public Member Functions

- RobinBCDescriptor2D ()

Default constructor.

- RobinBCDescriptor2D (const RobinBCDescriptor2D &desc)

  Copy constructor.
- ~RobinBCDescriptor2D () noexcept

  Destructor.
- int highest_order_diff_west () const noexcept

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

  Getter for the highest order of differentiation in the east boundary.
- int highest_order_diff_south () const noexcept

  Getter for the highest order of differentiation in the south boundary.
- int highest_order_diff_north () const noexcept

  Getter for the highest order of differentiation in the north boundary.
- void PushBackWestCoeff (CoefficientFunction1D cw)

  Push back coefficient function at west of lowest order diff. available.
- void PushBackEastCoeff (CoefficientFunction1D ce)

  Push back coefficient function at east of lowest order diff. available.
- void PushBackSouthCoeff (CoefficientFunction1D cs)

  Push back coefficient function south of lowest order diff. available.
- void PushBackNorthCoeff (CoefficientFunction1D cn)

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

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

  Set boundary condition at east.
- void set_south_condition (Real(*south_condition)(const Real &xx, const Real &tt)) noexcept

  Set boundary condition at south.
- void set_north_condition (Real(*north_condition)(const Real &xx, const Real &tt)) noexcept

  Set boundary condition at north.
- bool ImposeOnLaplacianMatrix (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the operator represented as matrix.
- void ImposeOnGrid (UniStgGrid2D &grid, const Real &time=kZero) const

  Imposes the condition on the grid.

Private Member Functions

- bool ImposeOnSouthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the south boundary.
- bool ImposeOnNorthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the north boundary.
- bool ImposeOnWestBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the west boundary.
- bool ImposeOnEastBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

Imposes the condition on the east boundary.

- bool ImposeOnSouthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the south boundary.

- bool ImposeOnNorthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the north boundary.

- bool ImposeOnWestBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the west boundary.

- bool ImposeOnEastBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the east boundary.

Private Attributes

- int highest_order_diff_west_

  Highest order of differentiation west.

- int highest_order_diff_east_

  Highest order of differentiation east.

- int highest_order_diff_south_

  Highest order differentiation for south.

- int highest_order_diff_north_

  Highest order differentiation for north.

- std::vector < CoefficientFunction1D > west_coefficients_

  Coeffs. west.

- std::vector < CoefficientFunction1D > east_coefficients_

  Coeffs. east.

- std::vector < CoefficientFunction1D > south_coefficients_

  Coeffs. south.

- std::vector < CoefficientFunction1D > north_coefficients_

  Coeffs. north.

- Real(* west_condition_)(const Real &xx, const Real &tt)

  Condition west.

- Real(* east_condition_)(const Real &xx, const Real &tt)

  Condition east.

- Real(* south_condition_)(const Real &yy, const Real &tt)

  Cond. south.

- Real(* north_condition_)(const Real &yy, const Real &tt)

  Cond. north.

17.20.1 Detailed Description

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

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Definition at line 132 of file mtk_robin_bc_descriptor_2d.h.

17.20.2 Constructor & Destructor Documentation

17.20.2.1 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D ( )

Definition at line 84 of file mtk_robin_bc_descriptor_2d.cc.

17.20.2.2 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D (const RobinBCDescriptor2D & *desc*)

Parameters

in	*desc*	Given 2D descriptor.

Definition at line 94 of file mtk_robin_bc_descriptor_2d.cc.

17.20.2.3 mtk::RobinBCDescriptor2D::~RobinBCDescriptor2D ( ) [noexcept]

Definition at line 105 of file mtk_robin_bc_descriptor_2d.cc.

17.20.3 Member Function Documentation

17.20.3.1 int mtk::RobinBCDescriptor2D::highest_order_diff_east ( ) const [noexcept]

Returns

Integer highest order of differentiation in the east boundary.

Definition at line 112 of file mtk_robin_bc_descriptor_2d.cc.

17.20.3.2 int mtk::RobinBCDescriptor2D::highest_order_diff_north ( ) const [noexcept]

Returns

Integer highest order of differentiation in the north boundary.

Definition at line 122 of file mtk_robin_bc_descriptor_2d.cc.

17.20.3.3 int mtk::RobinBCDescriptor2D::highest_order_diff_south ( ) const [noexcept]

Returns

Integer highest order of differentiation in the south boundary.

Definition at line 117 of file mtk_robin_bc_descriptor_2d.cc.

17.20.3.4 int mtk::RobinBCDescriptor2D::highest_order_diff_west ( ) const [noexcept]

Returns

Integer highest order of differentiation in the west boundary.

Definition at line 107 of file mtk_robin_bc_descriptor_2d.cc.

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

Parameters

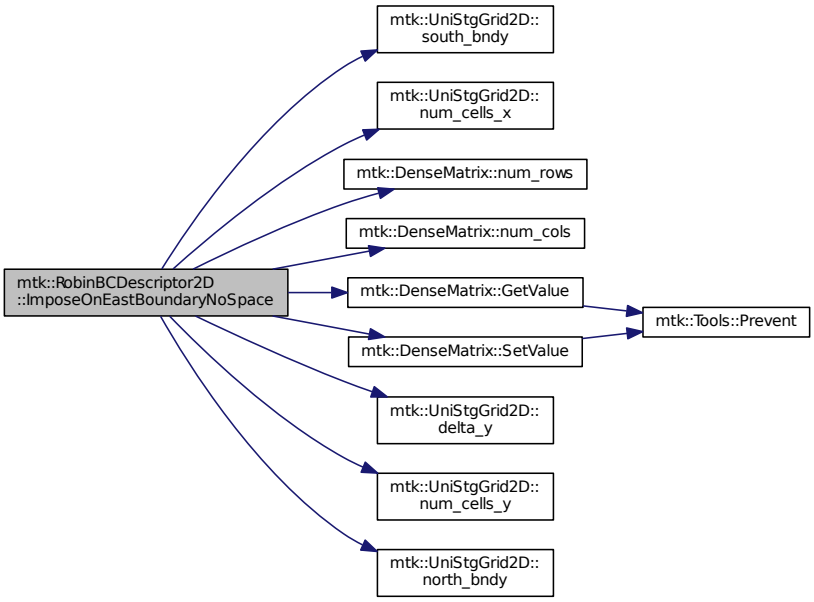
in	*lap*	Laplacian operator on the matrix.
in	*grid*	Grid upon which impose the desired boundary condition.
in,out	*matrix*	Input matrix with the Laplacian operator.
in	*time*	Current time snapshot. Default is kZero.

1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

Definition at line 495 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

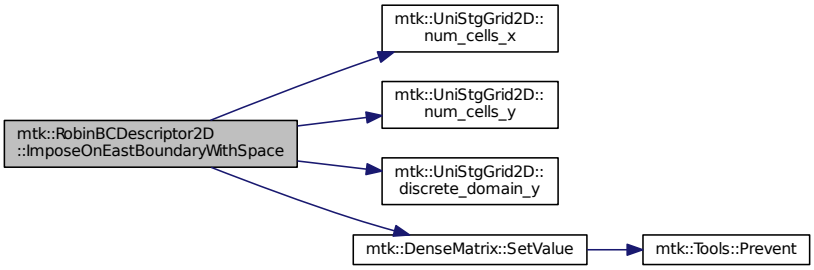
in	*lap*	Laplacian operator on the matrix.
in	*grid*	Grid upon which impose the desired boundary condition.
in,out	*matrix*	Input matrix with the Laplacian operator.
in	*time*	Current time snapshot. Default is kZero.

1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

Definition at line 564 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

in,out	*grid*	Grid upon which impose the desired boundary condition.
in	*time*	Current time snapshot. Default is kZero.

1. Impose assuming an scalar grid.

1.1. Impose south condition.

1.1.1. Impose south-west corner.

1.1.2. Impose south border.

1.1.3. Impose south-east corner.

1.2. Impose north condition.

1.2.1. Impose north-west corner.

1.2.2. Impose north border.

1.2.3. Impose north-east corner.

1.3. Impose west condition.

1.3.1. Impose south-west corner.

Note

As per discussion with Otilio, we will take the **arithmetic mean** of the values of the BCs at the corners.

1.3.2. Impose west border.

1.3.3. Impose north-west corner.

1.4. Impose east condition.

1.4.1. Impose south-east corner.

1.4.2. Impose east border.

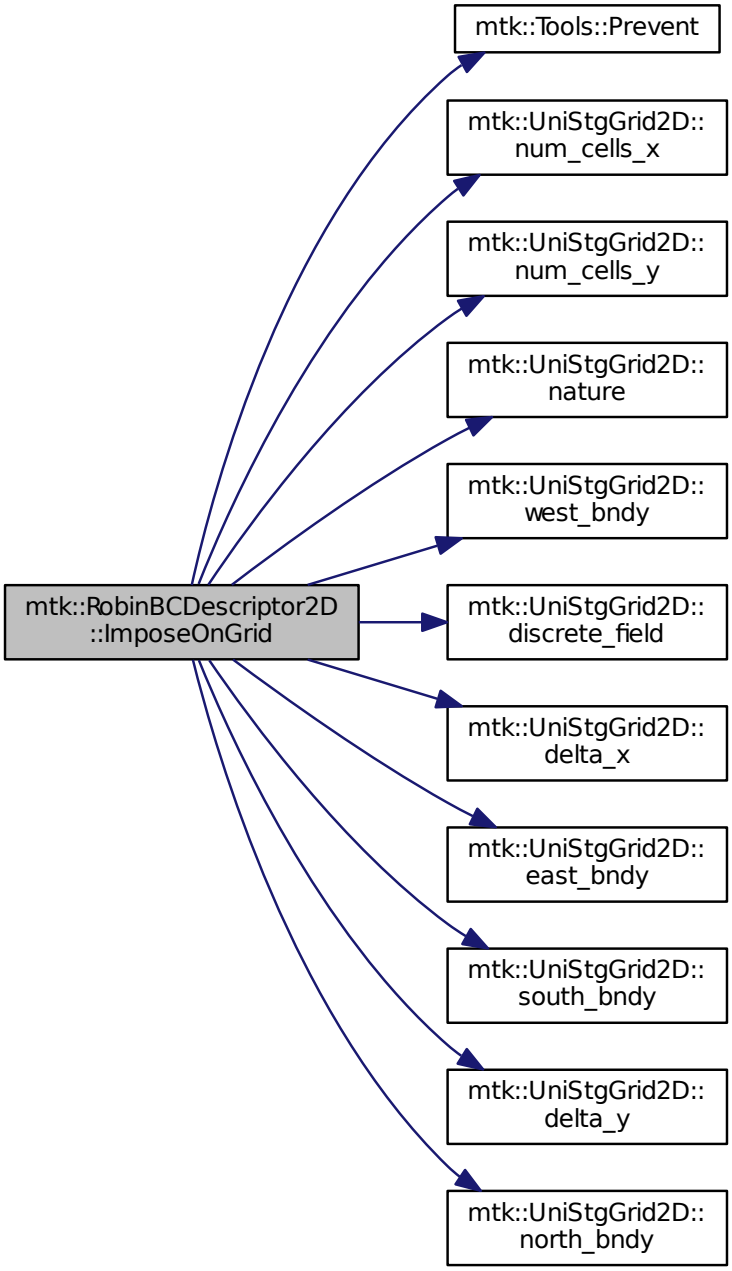
1.4.3. Impose north-east corner.

1. Impose assuming a vector grid.

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

Definition at line 674 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

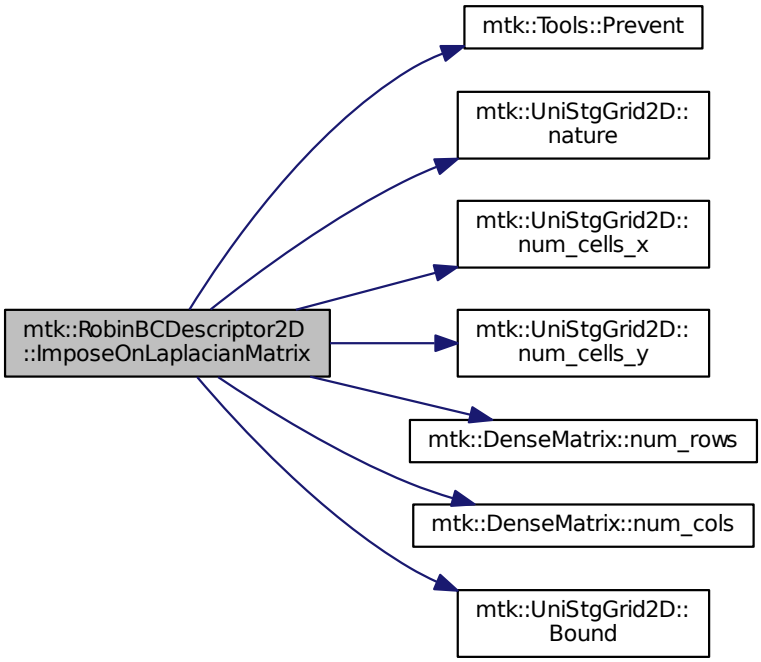
Parameters

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

If we have not bound anything to the grid, then we have to generate our collection of spatial coordinates, as we evaluate the coefficients.

Definition at line 591 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

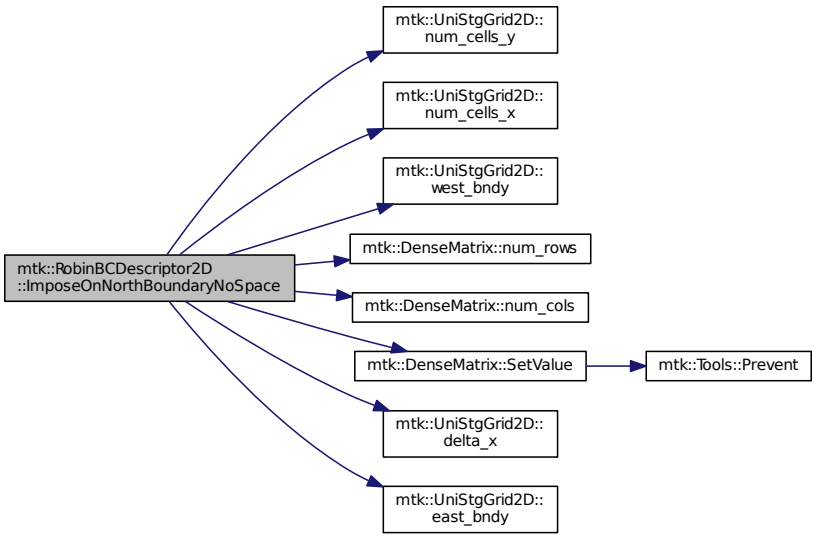
Parameters

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

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

Definition at line 312 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

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

1. Impose Dirichlet condition.

For each entry on the diagonal:

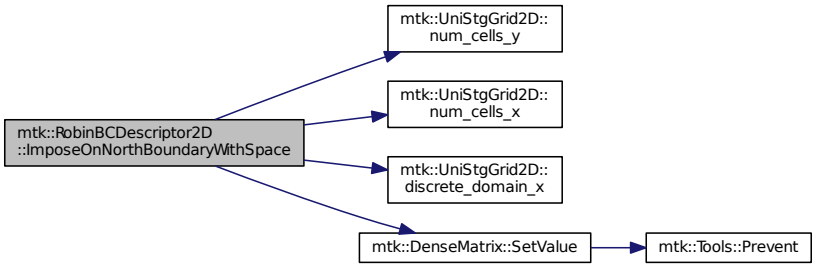
Evaluate next set spatial coordinates to evaluate the coefficient.

Evaluate and assign the Dirichlet coefficient.

1. Impose the Neumann condition.

Definition at line 372 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

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

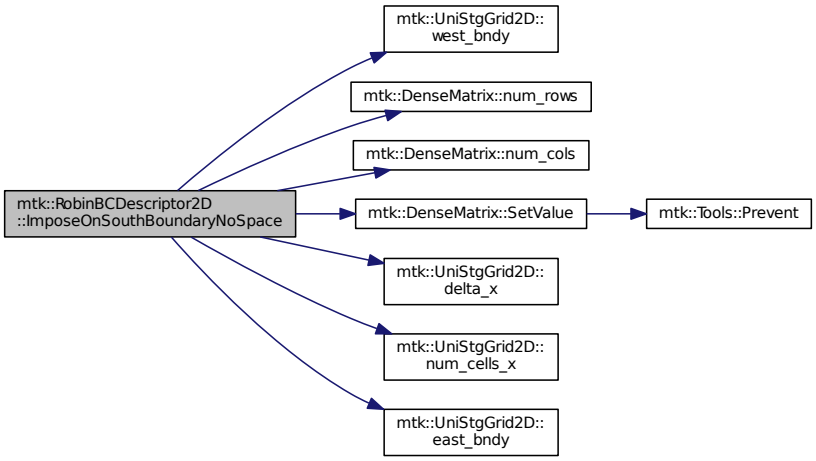
1. Impose the Dirichlet condition first.

2. Impose the Neumann condition.

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

Definition at line 229 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

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

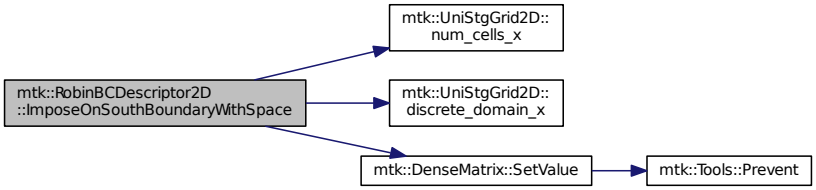
1. Impose the Dirichlet condition first.

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

1. Impose the Neumann condition.

Definition at line 284 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

Parameters

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

1. Impose the Dirichlet condition first.

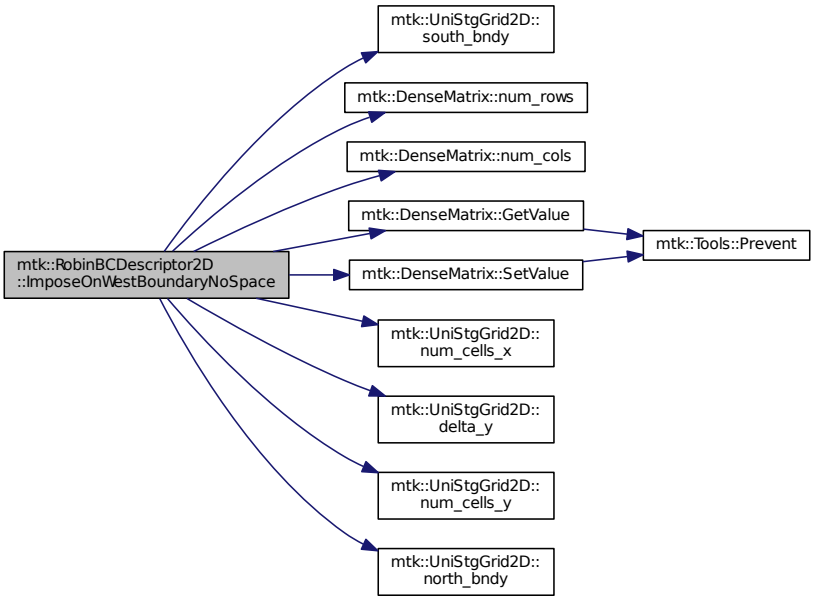
Note

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

1. Impose the Neumann condition.

Definition at line 399 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



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

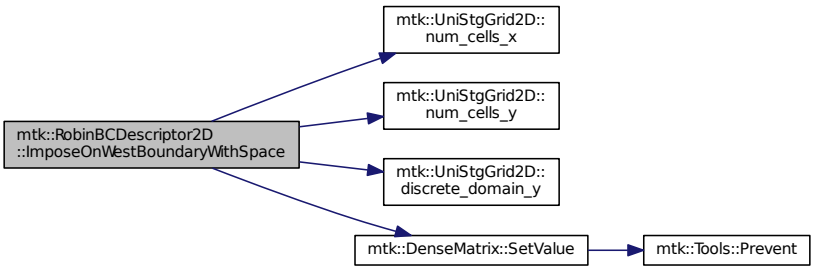
Parameters

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

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

Definition at line 468 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



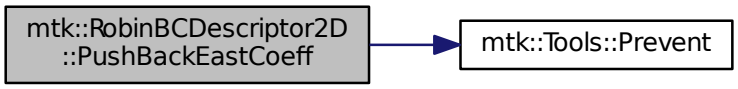
17.20.3.15 void mtk::RobinBCDescriptor2D::PushBackEastCoeff (mtk::CoefficientFunction1D *ce*)

Parameters

in	*cw*	Coeff. $c_e(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 141 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



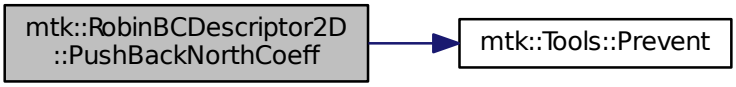
17.20.3.16 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff (mtk::CoefficientFunction1D *cn*)

Parameters

in	*cw*	Coeff. $c_n(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 169 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



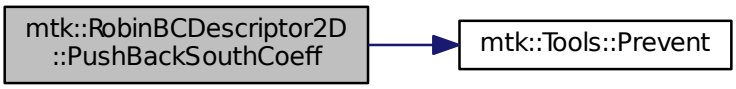
17.20.3.17 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff (mtk::CoefficientFunction1D *cs*)

Parameters

in	*cw*	Coeff. $c_s(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 155 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



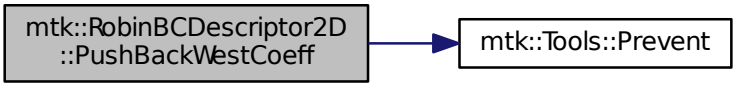
17.20.3.18 void mtk::RobinBCDescriptor2D::PushBackWestCoeff (mtk::CoefficientFunction1D *cw*)

Parameters

in	*cw*	Coeff. $c_w(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 127 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



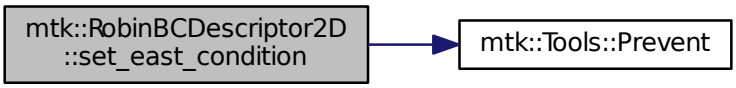
17.20.3.19 void mtk::RobinBCDescriptor2D::set_east_condition (Real(∗)(const Real &yy, const Real &tt) *east_condition*) [noexcept]

Parameters

in	*east_condition*	$\beta_e(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 194 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



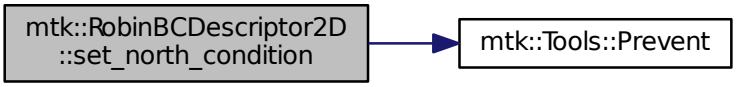
17.20.3.20 void mtk::RobinBCDescriptor2D::set_north_condition (Real(∗)(const Real &xx, const Real &tt) *north_condition*) [noexcept]

Parameters

in	*north_condition*	$\beta_n(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 217 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



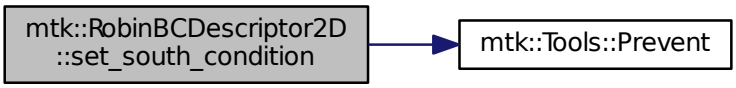
17.20.3.21 void mtk::RobinBCDescriptor2D::set_south_condition (Real(∗)(const Real &xx, const Real &tt) *south_condition*) [noexcept]

Parameters

in	*south_condition*	$\beta_s(x,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 205 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



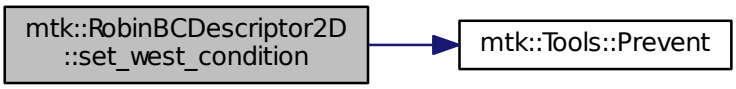
17.20.3.22 void mtk::RobinBCDescriptor2D::set_west_condition (Real(∗)(const Real &yy, const Real &tt) *west_condition*) [noexcept]

Parameters

in	*west_condition*	$\beta_w(y,t) : \partial\Omega \times [t_0, t_n] \mapsto \mathbb{R}$.

Definition at line 183 of file mtk_robin_bc_descriptor_2d.cc.

Here is the call graph for this function:



17.20.4 Member Data Documentation

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

Definition at line 367 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 372 of file mtk_robin_bc_descriptor_2d.h.

17.20.4.3 int mtk::RobinBCDescriptor2D::highest_order_diff_east_ [private]

Definition at line 362 of file mtk_robin_bc_descriptor_2d.h.

17.20.4.4 int mtk::RobinBCDescriptor2D::highest_order_diff_north_ [private]

Definition at line 364 of file mtk_robin_bc_descriptor_2d.h.

17.20.4.5 int mtk::RobinBCDescriptor2D::highest_order_diff_south_ [private]

Definition at line 363 of file mtk_robin_bc_descriptor_2d.h.

17.20.4.6 int mtk::RobinBCDescriptor2D::highest_order_diff_west_ [private]

Definition at line 361 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 369 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 374 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 368 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 373 of file mtk_robin_bc_descriptor_2d.h.

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

Definition at line 366 of file mtk_robin_bc_descriptor_2d.h.

17.20.4.12 Real(* mtk::RobinBCDescriptor2D::west_condition_)(const Real &xx, const Real &tt) [private]

Definition at line 371 of file mtk_robin_bc_descriptor_2d.h.

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

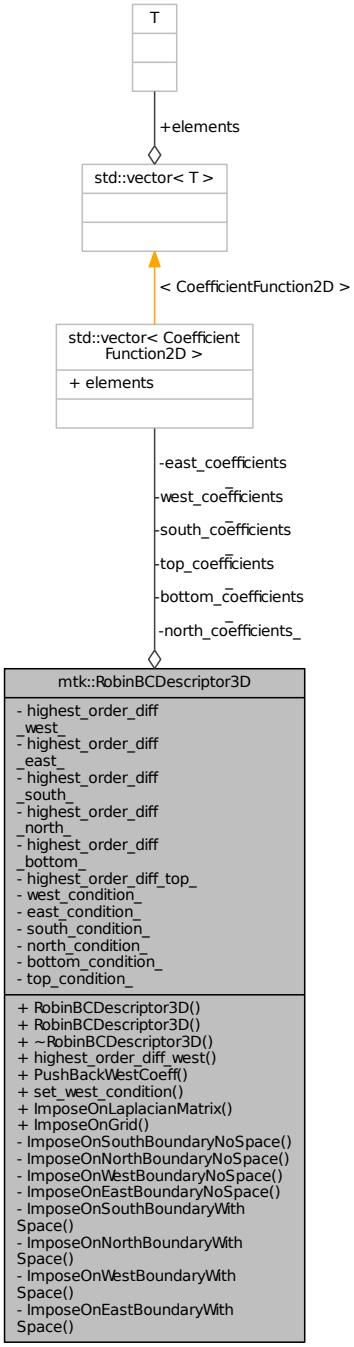
- include/mtk_robin_bc_descriptor_2d.h
- src/mtk_robin_bc_descriptor_2d.cc

17.21 mtk::RobinBCDescriptor3D Class Reference

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

`#include <mtk_robin_bc_descriptor_3d.h>`

Collaboration diagram for mtk::RobinBCDescriptor3D:



Public Member Functions

- RobinBCDescriptor3D ()

Default constructor.

- RobinBCDescriptor3D (const RobinBCDescriptor3D &desc)

  Copy constructor.

- ~RobinBCDescriptor3D () noexcept

  Destructor.

- int highest_order_diff_west () const noexcept

  *Getter for highest order of differentiation in the * face.*

- void PushBackWestCoeff (CoefficientFunction2D cw)

  Push back coefficient function at west lowest order diff. available.

- void set_west_condition (Real(*west_condition)(const Real &xx, const Real &yy, const Real &tt)) noexcept

  Set boundary condition at west.

- bool ImposeOnLaplacianMatrix (const Lap3D &lap, const UniStgGrid3D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the operator represented as matrix.

- void ImposeOnGrid (UniStgGrid3D &grid, const Real &time=kZero) const

  Imposes the condition on the grid.

Private Member Functions

- bool ImposeOnSouthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the south boundary.

- bool ImposeOnNorthBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the north boundary.

- bool ImposeOnWestBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the west boundary.

- bool ImposeOnEastBoundaryNoSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the east boundary.

- bool ImposeOnSouthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the south boundary.

- bool ImposeOnNorthBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the north boundary.

- bool ImposeOnWestBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the west boundary.

- bool ImposeOnEastBoundaryWithSpace (const Lap2D &lap, const UniStgGrid2D &grid, DenseMatrix &matrix, const Real &time=kZero) const

  Imposes the condition on the east boundary.

Private Attributes

- int highest_order_diff_west_

  Highest order of differentiation west.
- int highest_order_diff_east_

  Highest order of differentiation east.
- int highest_order_diff_south_

  Highest order differentiation for south.
- int highest_order_diff_north_

  Highest order differentiation for north.
- int highest_order_diff_bottom_

  Highest order differentiation bottom.
- int highest_order_diff_top_

  Highest order differentiation for top.
- std::vector < CoefficientFunction2D > west_coefficients_

  Coeffs. west.
- std::vector < CoefficientFunction2D > east_coefficients_

  Coeffs. east.
- std::vector < CoefficientFunction2D > south_coefficients_

  Coeffs. south.
- std::vector < CoefficientFunction2D > north_coefficients_

  Coeffs. north.
- std::vector < CoefficientFunction2D > bottom_coefficients_

  Coeffs. bottom.
- std::vector < CoefficientFunction2D > top_coefficients_

  Coeffs. top.
- Real(* west_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Condition west.
- Real(* east_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Condition east.
- Real(* south_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Cond. south.
- Real(* north_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Cond. north.
- Real(* bottom_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Cond. bottom.
- Real(* top_condition_)(const Real &xx, const Real &yy, const Real &tt)

  Cond. top.

17.21.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 3D mimetic operators and the grids they are acting on.

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary. These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Definition at line 134 of file mtk_robin_bc_descriptor_3d.h.

17.21.2 Constructor & Destructor Documentation

17.21.2.1 mtk::RobinBCDescriptor3D::RobinBCDescriptor3D ( )

17.21.2.2 mtk::RobinBCDescriptor3D::RobinBCDescriptor3D (const RobinBCDescriptor3D & *desc*)

Parameters

in	*desc*	Given 2D descriptor.

17.21.2.3 mtk::RobinBCDescriptor3D::~RobinBCDescriptor3D ( ) [noexcept]

17.21.3 Member Function Documentation

17.21.3.1 int mtk::RobinBCDescriptor3D::highest_order_diff_west ( ) const [noexcept]

Returns

Integer highest order of differentiation in the $*$ face.

17.21.3.2 bool mtk::RobinBCDescriptor3D::ImposeOnEastBoundaryNoSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.3 bool mtk::RobinBCDescriptor3D::ImposeOnEastBoundaryWithSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.4 void mtk::RobinBCDescriptor3D::ImposeOnGrid (UniStgGrid3D & *grid*, const Real & *time* = kZero) const

Parameters

in,out	*grid*	Grid upon which impose the desired boundary condition.
in	*time*	Current time snapshot. Default is kZero.

17.21.3.5 bool mtk::RobinBCDescriptor3D::ImposeOnLaplacianMatrix (const Lap3D & *lap*, const UniStgGrid3D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const

Parameters

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

17.21.3.6 bool mtk::RobinBCDescriptor3D::ImposeOnNorthBoundaryNoSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.7 bool mtk::RobinBCDescriptor3D::ImposeOnNorthBoundaryWithSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.8 bool mtk::RobinBCDescriptor3D::ImposeOnSouthBoundaryNoSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.9 bool mtk::RobinBCDescriptor3D::ImposeOnSouthBoundaryWithSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.10 bool mtk::RobinBCDescriptor3D::ImposeOnWestBoundaryNoSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

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

17.21.3.11 bool mtk::RobinBCDescriptor3D::ImposeOnWestBoundaryWithSpace (const Lap2D & *lap*, const UniStgGrid2D & *grid*, DenseMatrix & *matrix*, const Real & *time* = kZero) const [private]

Parameters

in	*lap*	Laplacian operator on the matrix.
in	*grid*	Grid upon which impose the desired boundary condition.
in,out	*matrix*	Input matrix with the Laplacian operator.

in	*time*	Current time snapshot. Default is kZero.

17.21.3.12 void mtk::RobinBCDescriptor3D::PushBackWestCoeff (CoefficientFunction2D *cw*)

Parameters

in	*cw*	Coeff. $c_w(x,y,t) : \partial\Omega \times [t_0,t_n] \mapsto \mathbb{R}$.

17.21.3.13 void mtk::RobinBCDescriptor3D::set_west_condition (Real(∗)(const Real &xx, const Real &yy, const Real &tt) *west_condition*) [noexcept]

Parameters

in	*west_condition*	$\beta_w(x,y,t) : \partial\Omega \times [t_0,t_n] \mapsto \mathbb{R}$.

17.21.4 Member Data Documentation

17.21.4.1 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::bottom_coefficients_ [private]

Definition at line 309 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.2 Real(∗ mtk::RobinBCDescriptor3D::bottom_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 324 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.3 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::east_coefficients_ [private]

Definition at line 306 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.4 Real(∗ mtk::RobinBCDescriptor3D::east_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 315 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.5 int mtk::RobinBCDescriptor3D::highest_order_diff_bottom_ [private]

Definition at line 302 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.6 int mtk::RobinBCDescriptor3D::highest_order_diff_east_ [private]

Definition at line 299 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.7 int mtk::RobinBCDescriptor3D::highest_order_diff_north_ [private]

Definition at line 301 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.8 int mtk::RobinBCDescriptor3D::highest_order_diff_south_ [private]

Definition at line 300 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.9 int mtk::RobinBCDescriptor3D::highest_order_diff_top_ [private]

Definition at line 303 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.10 int mtk::RobinBCDescriptor3D::highest_order_diff_west_ [private]

Definition at line 298 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.11 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::north_coefficients_ [private]

Definition at line 308 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.12 Real(* mtk::RobinBCDescriptor3D::north_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 321 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.13 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::south_coefficients_ [private]

Definition at line 307 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.14 Real(* mtk::RobinBCDescriptor3D::south_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 318 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.15 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::top_coefficients_ [private]

Definition at line 310 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.16 Real(* mtk::RobinBCDescriptor3D::top_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 327 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.17 std::vector<CoefficientFunction2D> mtk::RobinBCDescriptor3D::west_coefficients_ [private]

Definition at line 305 of file mtk_robin_bc_descriptor_3d.h.

17.21.4.18 Real(∗ mtk::RobinBCDescriptor3D::west_condition_)(const Real &xx, const Real &yy, const Real &tt) [private]

Definition at line 312 of file mtk_robin_bc_descriptor_3d.h.

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

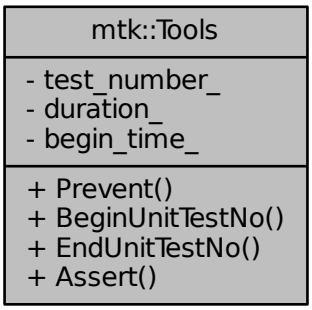
- include/mtk_robin_bc_descriptor_3d.h

17.22 mtk::Tools Class Reference

Tool manager class.

`#include <mtk_tools.h>`

Collaboration diagram for mtk::Tools:



Static Public Member Functions

- static void Prevent (const bool complement, const char ∗const fname, int lineno, const char ∗const fxname) noexcept

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

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

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

  Asserts if the condition required to pass the unit test occurs.

Static Private Attributes

- static int test_number_

  Current test being executed.

- static Real duration_ {}

  Duration of the current test.

- static clock_t begin_time_ {}

  Elapsed time on current test.

17.22.1 Detailed Description

Basic tools to ensure execution correctness, and to assists with unitary testing.

Definition at line 80 of file mtk_tools.h.

17.22.2 Member Function Documentation

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

Parameters

in	*condition*	Condition to be asserted.

Definition at line 108 of file mtk_tools.cc.

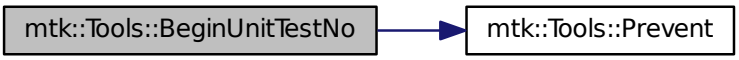
17.22.2.2 void mtk::Tools::BeginUnitTestNo (const int & *nn*) [static], [noexcept]

Parameters

in	*nn*	Number of the test.

Definition at line 87 of file mtk_tools.cc.

Here is the call graph for this function:



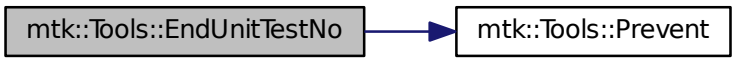
17.22.2.3 void mtk::Tools::EndUnitTestNo (const int & *nn*) [static], [noexcept]

Parameters

in	*nn*	Number of the test.

Definition at line 99 of file mtk_tools.cc.

Here is the call graph for this function:



17.22.2.4 void mtk::Tools::Prevent (const bool *complement*, const char *const *const *fname*, int *lineno*, const char *const *const *fxname*) [static], [noexcept]

See also

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

Parameters

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

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

Definition at line 62 of file mtk_tools.cc.

17.22.3 Member Data Documentation

17.22.3.1 clock_t mtk::Tools::begin_time_ {} [static], [private]

Definition at line 123 of file mtk_tools.h.

17.22.3.2 mtk::Real mtk::Tools::duration_ {} [static], [private]

Definition at line 121 of file mtk_tools.h.

17.22.3.3 int mtk::Tools::test_number_ [static], [private]

Definition at line 119 of file mtk_tools.h.

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

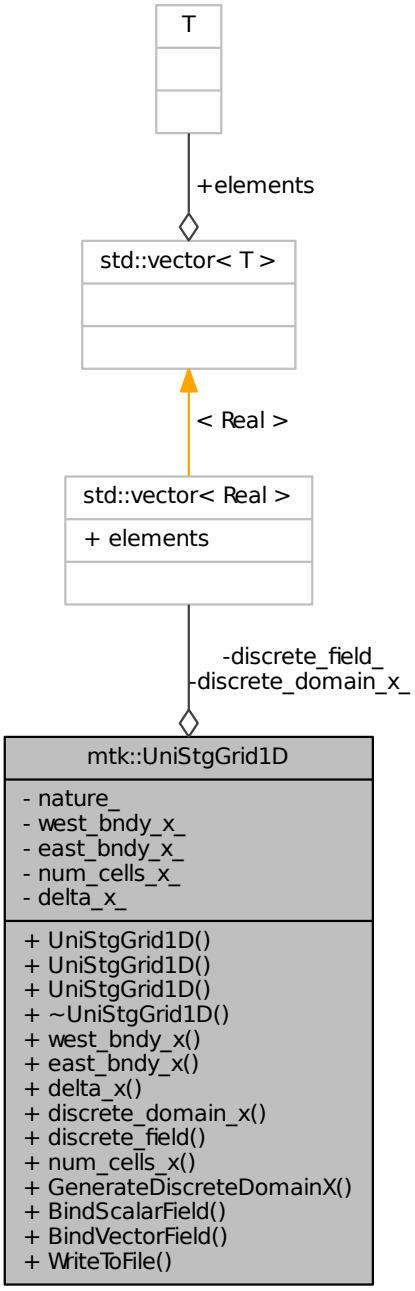
- include/mtk_tools.h
- src/mtk_tools.cc

17.23 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::FieldNature::SCALAR)

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

  Destructor.
- Real west_bndy_x () const

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

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

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

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

  Provides access to the grid field data.
- int num_cells_x () const

  Provides access to the number of cells of the grid.
- void GenerateDiscreteDomainX ()

  Generate the actual set of spatial coordinates.
- void BindScalarField (Real(*ScalarField)(const Real &xx))

  Binds a given scalar field to the grid.
- void BindVectorField (Real(*VectorField)(Real xx))

  Binds a given vector field to the grid.
- bool WriteToFile (std::string filename, std::string space_name, std::string field_name) const

  Writes grid to a file compatible with gnuplot 4.6.

Private Attributes

- FieldNature nature_

  Nature of the discrete field.
- std::vector< Real > discrete_domain_x_

  Array of spatial data.
- std::vector< Real > discrete_field_

  Array of field's data.
- Real west_bndy_x_

  West boundary spatial coordinate.
- Real east_bndy_x_

  East boundary spatial coordinate.
- Real num_cells_x_

  Number of cells discretizing the domain.
- Real delta_x_

  Produced Δx.

Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid1D &in)
  Prints the grid as a tuple of arrays.

17.23.1 Detailed Description

Uniform 1D Staggered Grid.

Definition at line 77 of file mtk_uni_stg_grid_1d.h.

17.23.2 Constructor & Destructor Documentation

17.23.2.1 mtk::UniStgGrid1D::UniStgGrid1D ( )

Definition at line 99 of file mtk_uni_stg_grid_1d.cc.

17.23.2.2 mtk::UniStgGrid1D::UniStgGrid1D (const UniStgGrid1D & *grid*)

Parameters

in	*grid*	Given grid.

Definition at line 108 of file mtk_uni_stg_grid_1d.cc.

17.23.2.3 mtk::UniStgGrid1D::UniStgGrid1D (const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const mtk::FieldNature & *nature* = mtk::FieldNature::SCALAR)

Parameters

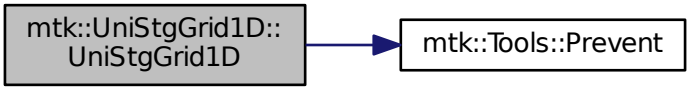
in	*west_bndy_x*	Coordinate for the west boundary.
in	*east_bndy_x*	Coordinate for the east boundary.
in	*num_cells_x*	Number of cells of the required grid.
in	*nature*	Nature of the discrete field to hold.

See also

mtk::FieldNature

Definition at line 124 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



17.23.2.4 mtk::UniStgGrid1D::∼UniStgGrid1D ( )

Definition at line 144 of file mtk_uni_stg_grid_1d.cc.

17.23.3 Member Function Documentation

17.23.3.1 void mtk::UniStgGrid1D::BindScalarField (Real(∗)(const Real &xx) *ScalarField*)

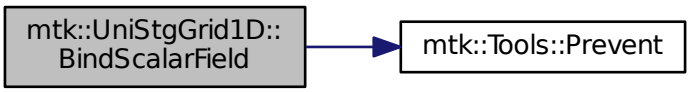
Parameters

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

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

Definition at line 211 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



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

We assume the field to be of the form:

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

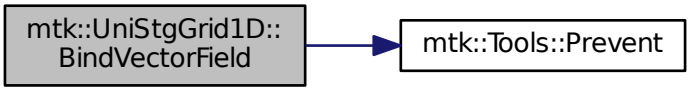
Parameters

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

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

Definition at line 248 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



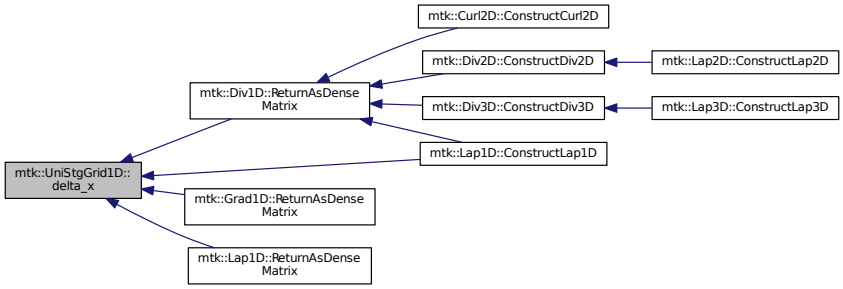
17.23.3.3 mtk::Real mtk::UniStgGrid1D::delta_x ( ) const

Returns

Computed $ x $.

Definition at line 156 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:



17.23.3.4 const mtk::Real * mtk::UniStgGrid1D::discrete_domain_x ( ) const

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 161 of file mtk_uni_stg_grid_1d.cc.

17.23.3.5 mtk::Real * mtk::UniStgGrid1D::discrete_field ( )

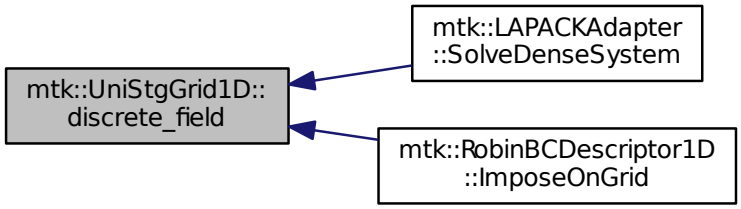
Returns

Pointer to the field data.

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

Definition at line 166 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:



17.23.3.6 mtk::Real mtk::UniStgGrid1D::east_bndy_x ( ) const

Returns

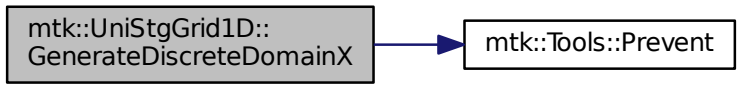
East boundary spatial coordinate.

Definition at line 151 of file mtk_uni_stg_grid_1d.cc.

17.23.3.7 void mtk::UniStgGrid1D::GenerateDiscreteDomainX ( )

Definition at line 176 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



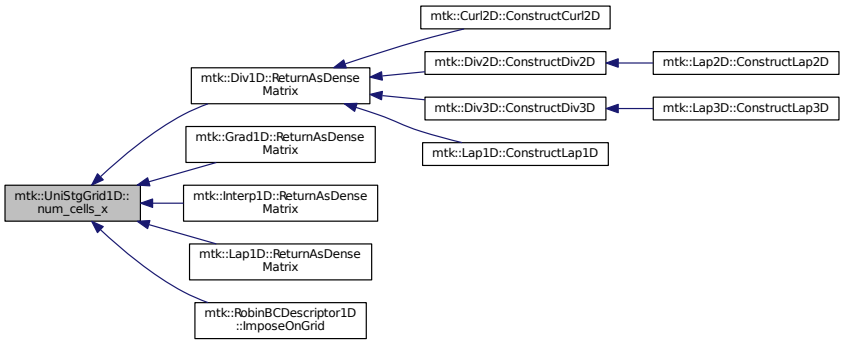
17.23.3.8 int mtk::UniStgGrid1D::num_cells_x ( ) const

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:



17.23.3.9 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.

17.23.3.10 bool mtk::UniStgGrid1D::WriteToFile (std::string *filename*, std::string *space_name*, std::string *field_name*) const

Parameters

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

Returns

Success of the file writing process.

See also

http://www.gnuplot.info/

Definition at line 277 of file mtk_uni_stg_grid_1d.cc.

17.23.4 Friends And Related Function Documentation

17.23.4.1 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.

17.23.5 Member Data Documentation

17.23.5.1 Real mtk::UniStgGrid1D::delta_x_ [private]

Definition at line 204 of file mtk_uni_stg_grid_1d.h.

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

Definition at line 198 of file mtk_uni_stg_grid_1d.h.

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

Definition at line 199 of file mtk_uni_stg_grid_1d.h.

17.23.5.4 Real mtk::UniStgGrid1D::east_bndy_x_ [private]

Definition at line 202 of file mtk_uni_stg_grid_1d.h.

17.23.5.5 FieldNature mtk::UniStgGrid1D::nature_ [private]

Definition at line 196 of file mtk_uni_stg_grid_1d.h.

17.23.5.6 Real mtk::UniStgGrid1D::num_cells_x_ [private]

Definition at line 203 of file mtk_uni_stg_grid_1d.h.

17.23.5.7 Real mtk::UniStgGrid1D::west_bndy_x_ [private]

Definition at line 201 of file mtk_uni_stg_grid_1d.h.

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

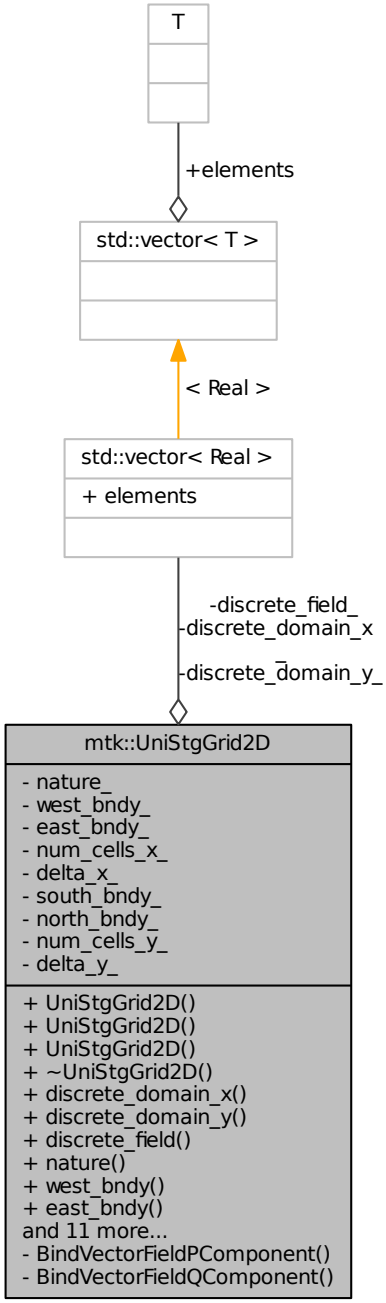
- include/mtk_uni_stg_grid_1d.h
- src/mtk_uni_stg_grid_1d.cc

17.24 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::Field↩ Nature::SCALAR)

  Construct a grid based on spatial discretization parameters.

- ∼UniStgGrid2D ()

  Destructor.

- const Real ∗ discrete_domain_x () const

  Provides access to the grid spatial data.

- const Real ∗ discrete_domain_y () const

  Provides access to the grid spatial data.

- Real ∗ discrete_field ()

  Provides access to the grid field data.

- FieldNature nature () const

  Physical nature of the data bound to the grid.

- Real west_bndy () const

  Provides access to west boundary spatial coordinate.

- Real east_bndy () const

  Provides access to east boundary spatial coordinate.

- int num_cells_x () const

  Provides access to the number of cells of the grid.

- Real delta_x () const

  Provides access to the computed $ x $.

- Real south_bndy () const

  Provides access to south boundary spatial coordinate.

- Real north_bndy () const

  Provides access to north boundary spatial coordinate.

- int num_cells_y () const

  Provides access to the number of cells of the grid.

- Real delta_y () const

  Provides access to the computed $ y $.

- bool Bound () const

  Have any field been bound to the grid?

- int Size () const

  Total number of samples in the grid.

- void BindScalarField (Real(∗ScalarField)(const Real &xx, const Real &yy))

  Binds a given scalar field to the grid.

- void BindVectorField (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy), Real(∗VectorFieldQ↩ Component)(const Real &xx, const Real &yy))

  Binds a given vector field to the grid.

- bool WriteToFile (std::string filename, std::string space_name_x, std::string space_name_y, std::string field_↩ name) const

  Writes grid to a file compatible with Gnuplot 4.6.

Private Member Functions

- void BindVectorFieldPComponent (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy))

  Binds a given component of a vector field to the grid.
- void BindVectorFieldQComponent (Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy))

  Binds a given component of a vector field to the grid.

Private Attributes

- std::vector< Real > discrete_domain_x_

  Array of spatial data.
- std::vector< Real > discrete_domain_y_

  Array of spatial data.
- std::vector< Real > discrete_field_

  Array of field's data.
- FieldNature nature_

  Nature of the discrete field.
- Real west_bndy_

  West boundary spatial coordinate.
- Real east_bndy_

  East boundary spatial coordinate.
- int num_cells_x_

  Number of cells discretizing the domain.
- Real delta_x_

  Computed Δx.
- 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 Δy.

Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid2D &in)

  Prints the grid as a tuple of arrays.

17.24.1 Detailed Description

Uniform 2D Staggered Grid.

Definition at line 79 of file mtk_uni_stg_grid_2d.h.

17.24.2 Constructor & Destructor Documentation

17.24.2.1 mtk::UniStgGrid2D::UniStgGrid2D ( )

Definition at line 132 of file mtk_uni_stg_grid_2d.cc.

17.24.2.2 mtk::UniStgGrid2D::UniStgGrid2D (const UniStgGrid2D & *grid*)

Parameters

in	*grid*	Given grid.

Definition at line 146 of file mtk_uni_stg_grid_2d.cc.

17.24.2.3 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::FieldNature::SCALAR)

Parameters

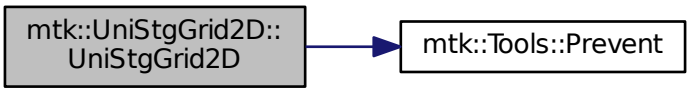
in	*west_bndy_x*	Coordinate for the west boundary.
in	*east_bndy_x*	Coordinate for the east boundary.
in	*num_cells_x*	Number of cells of the required grid.
in	*south_bndy_y*	Coordinate for the west boundary.
in	*north_bndy_y*	Coordinate for the east boundary.
in	*num_cells_y*	Number of cells of the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

See also

mtk::FieldNature

Definition at line 170 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:



17.24.2.4 mtk::UniStgGrid2D::~UniStgGrid2D ( )

Definition at line 204 of file mtk_uni_stg_grid_2d.cc.

17.24.3 Member Function Documentation

17.24.3.1 void mtk::UniStgGrid2D::BindScalarField (Real(∗)(const Real &xx, const Real &yy) *ScalarField*)

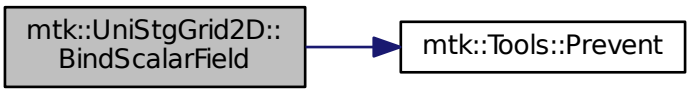
Parameters

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

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

Definition at line 276 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:



17.24.3.2 void mtk::UniStgGrid2D::BindVectorField (Real(∗)(const Real &xx, const Real &yy) *VectorFieldPComponent*, Real(∗)(const Real &xx, const Real &yy) *VectorFieldQComponent*)

We assume the field to be of the form:

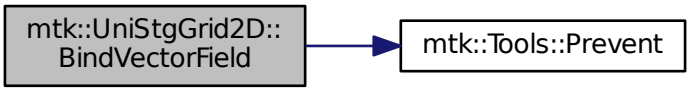
$$\mathbf{v}(\mathbf{x}) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

Parameters

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

Definition at line 425 of file mtk_uni_stg_grid_2d.cc.

Here is the call graph for this function:



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

We assume the field to be of the form:

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

Parameters

in	*BindVectorField↩ PComponent*	Pointer to the function implementing the $ p $ component of the vector field.

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

Definition at line 332 of file mtk_uni_stg_grid_2d.cc.

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

We assume the field to be of the form:

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

Parameters

in	*BindVectorField↩ QComponent*	Pointer to the function implementing the $ q $ component of the vector field.

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

Definition at line 397 of file mtk_uni_stg_grid_2d.cc.

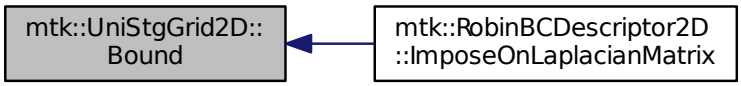
17.24.3.5 bool mtk::UniStgGrid2D::Bound ( ) const

Returns

True is a field has been bound.

Definition at line 256 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



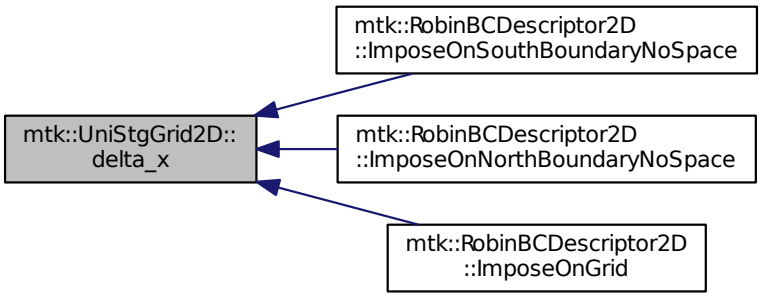
17.24.3.6 mtk::Real mtk::UniStgGrid2D::delta_x ( ) const

Returns

Computed $ x $.

Definition at line 226 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



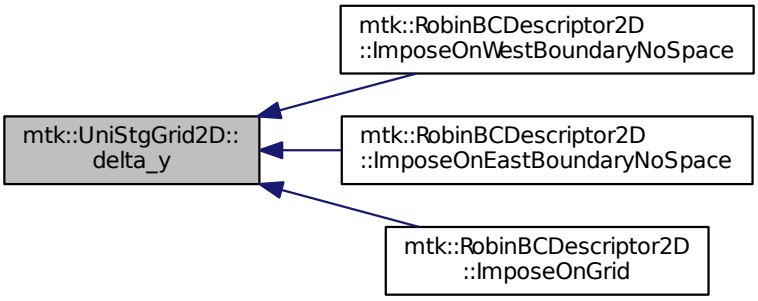
17.24.3.7 mtk::Real mtk::UniStgGrid2D::delta_y ( ) const

Returns

Computed $ y $.

Definition at line 251 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



17.24.3.8 const mtk::Real * mtk::UniStgGrid2D::discrete_domain_x ( ) const

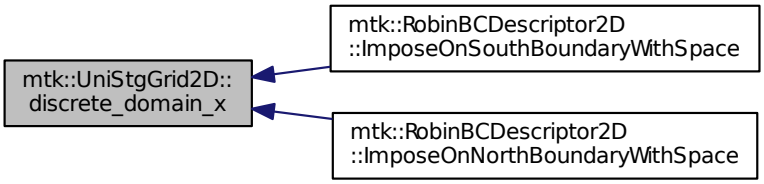
Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 231 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



17.24.3.9 const mtk::Real * mtk::UniStgGrid2D::discrete_domain_y ( ) const

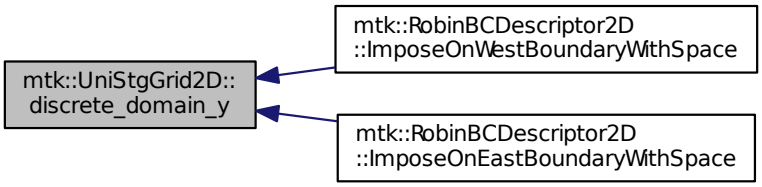
Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 261 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



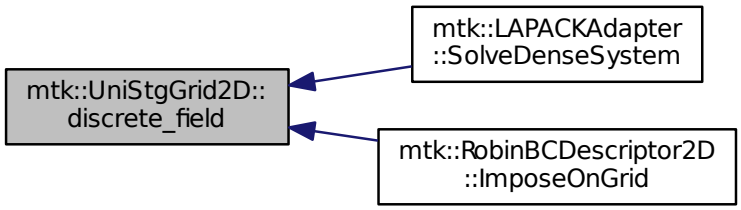
17.24.3.10 mtk::Real * mtk::UniStgGrid2D::discrete_field ( )

Returns

Pointer to the field data.

Definition at line 266 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



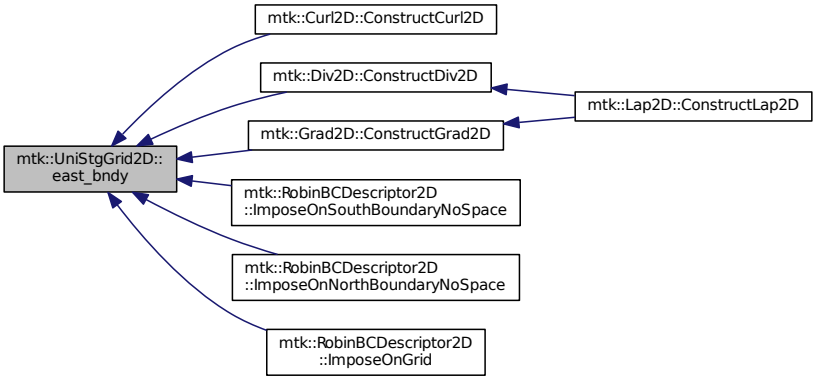
17.24.3.11 mtk::Real mtk::UniStgGrid2D::east_bndy ( ) const

Returns

East boundary spatial coordinate.

Definition at line 216 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



17.24.3.12 mtk::FieldNature mtk::UniStgGrid2D::nature ( ) const

Returns

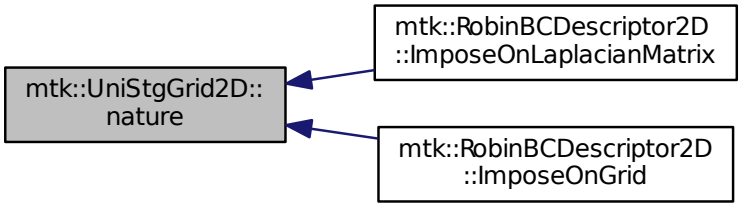
Value of an enumeration.

See also

mtk::FieldNature

Definition at line 206 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



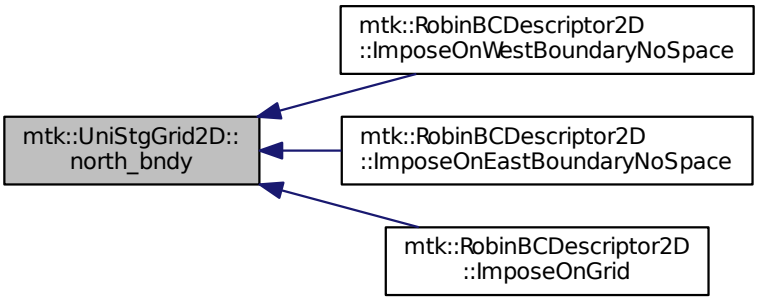
17.24.3.13 mtk::Real mtk::UniStgGrid2D::north_bndy ( ) const

Returns

North boundary spatial coordinate.

Definition at line 241 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



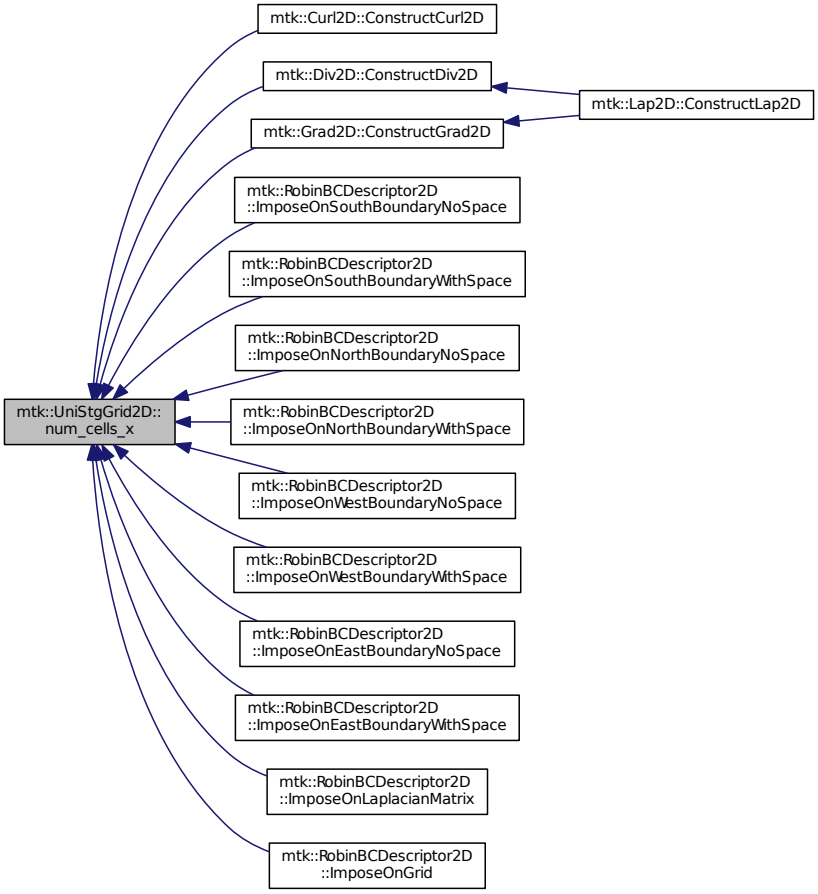
17.24.3.14 int mtk::UniStgGrid2D::num_cells_x ( ) const

Returns

Number of cells of the grid.

Definition at line 221 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



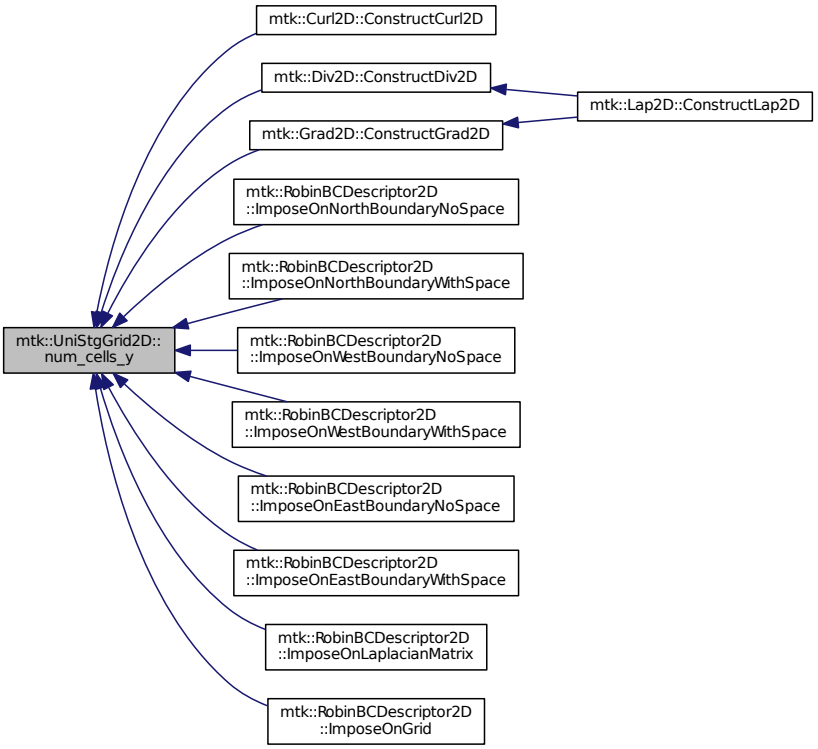
17.24.3.15 int mtk::UniStgGrid2D::num_cells_y ( ) const

Returns

Number of cells of the grid.

Definition at line 246 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



17.24.3.16 int mtk::UniStgGrid2D::Size ( ) const

Returns

Total number of samples in the grid.

Definition at line 271 of file mtk_uni_stg_grid_2d.cc.

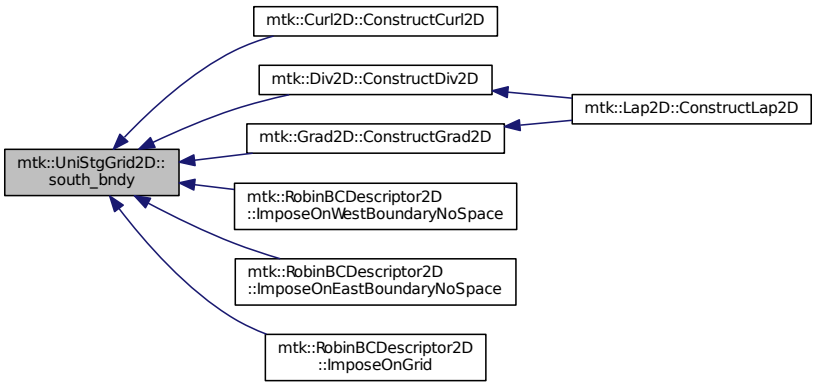
17.24.3.17 mtk::Real mtk::UniStgGrid2D::south_bndy ( ) const

Returns

South boundary spatial coordinate.

Definition at line 236 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



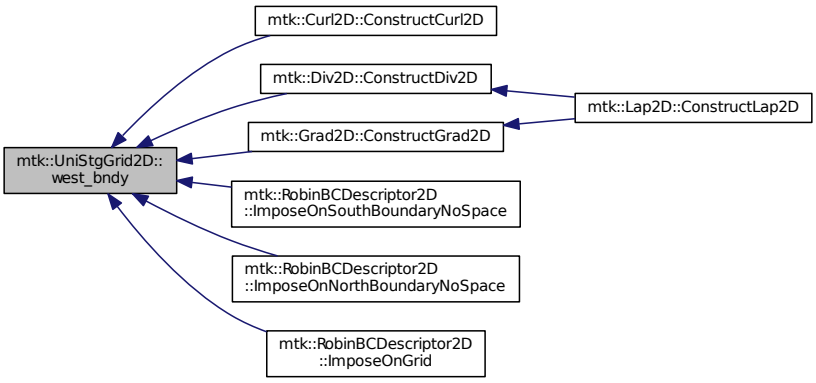
17.24.3.18 mtk::Real mtk::UniStgGrid2D::west_bndy ( ) const

Returns

West boundary spatial coordinate.

Definition at line 211 of file mtk_uni_stg_grid_2d.cc.

Here is the caller graph for this function:



17.24.3.19 bool mtk::UniStgGrid2D::WriteToFile (std::string *filename,* std::string *space_name_x,* std::string *space_name_y,* std::string *field_name*) const

Parameters

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

Returns

Success of the file writing process.

See also

http://www.gnuplot.info/

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

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

Definition at line 438 of file mtk_uni_stg_grid_2d.cc.

17.24.4 Friends And Related Function Documentation

17.24.4.1 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.

17.24.5 Member Data Documentation

17.24.5.1 Real mtk::UniStgGrid2D::delta_x_ [private]

Definition at line 302 of file mtk_uni_stg_grid_2d.h.

17.24.5.2 Real mtk::UniStgGrid2D::delta_y_ [private]

Definition at line 307 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 293 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 294 of file mtk_uni_stg_grid_2d.h.

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

Definition at line 295 of file mtk_uni_stg_grid_2d.h.

17.24.5.6 Real mtk::UniStgGrid2D::east_bndy_ [private]

Definition at line 300 of file mtk_uni_stg_grid_2d.h.

17.24.5.7 FieldNature mtk::UniStgGrid2D::nature_ [private]

Definition at line 297 of file mtk_uni_stg_grid_2d.h.

17.24.5.8 Real mtk::UniStgGrid2D::north_bndy_ [private]

Definition at line 305 of file mtk_uni_stg_grid_2d.h.

17.24.5.9 int mtk::UniStgGrid2D::num_cells_x_ [private]

Definition at line 301 of file mtk_uni_stg_grid_2d.h.

17.24.5.10 int mtk::UniStgGrid2D::num_cells_y_ [private]

Definition at line 306 of file mtk_uni_stg_grid_2d.h.

17.24.5.11 Real mtk::UniStgGrid2D::south_bndy_ [private]

Definition at line 304 of file mtk_uni_stg_grid_2d.h.

17.24.5.12 Real mtk::UniStgGrid2D::west_bndy_ [private]

Definition at line 299 of file mtk_uni_stg_grid_2d.h.

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

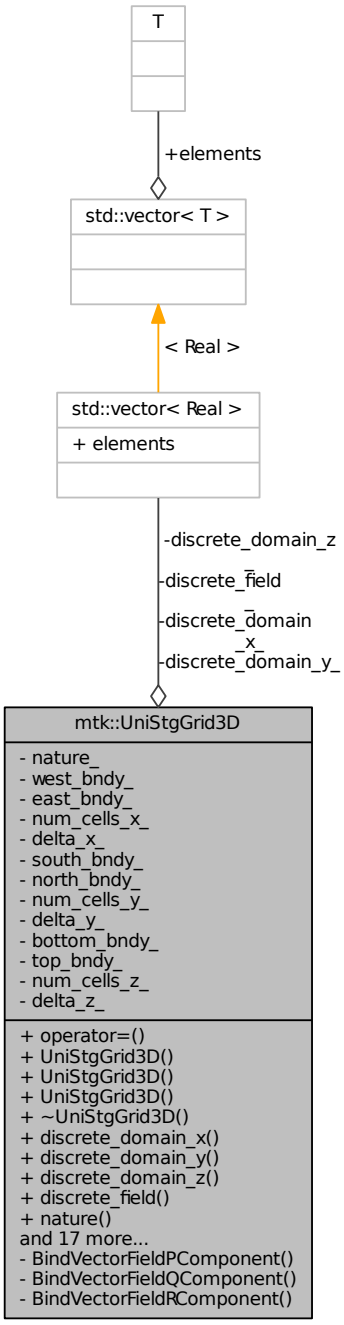
- include/mtk_uni_stg_grid_2d.h
- src/mtk_uni_stg_grid_2d.cc

17.25 mtk::UniStgGrid3D Class Reference

Uniform 3D Staggered Grid.

`#include <mtk_uni_stg_grid_3d.h>`

Collaboration diagram for mtk::UniStgGrid3D:



Public Member Functions

- UniStgGrid3D operator= (const UniStgGrid3D &in)

Overloaded assignment operator.

- UniStgGrid3D ()

  Default constructor.

- UniStgGrid3D (const UniStgGrid3D &grid)

  Copy constructor.

- UniStgGrid3D (const Real &west_bndy_x, const Real &east_bndy_x, const int &num_cells_x, const Real &south_bndy_y, const Real &north_bndy_y, const int &num_cells_y, const Real &bottom_bndy_z, const Real &top_bndy_z, const int &num_cells_z, const mtk::FieldNature &nature=mtk::FieldNature::SCALAR)

  Construct a grid based on spatial discretization parameters.

- ~UniStgGrid3D ()

  Destructor.

- const Real * discrete_domain_x () const

  Provides access to the grid spatial data.

- const Real * discrete_domain_y () const

  Provides access to the grid spatial data.

- const Real * discrete_domain_z () const

  Provides access to the grid spatial data.

- Real * discrete_field ()

  Provides access to the grid field data.

- FieldNature nature () const

  Physical nature of the data bound to the grid.

- Real west_bndy () const

  Provides access to west boundary spatial coordinate.

- Real east_bndy () const

  Provides access to east boundary spatial coordinate.

- int num_cells_x () const

  Provides access to the number of cells of the grid.

- Real delta_x () const

  Provides access to the computed $ x $.

- Real south_bndy () const

  Provides access to south boundary spatial coordinate.

- Real north_bndy () const

  Provides access to north boundary spatial coordinate.

- int num_cells_y () const

  Provides access to the number of cells of the grid.

- Real delta_y () const

  Provides access to the computed $ y $.

- Real bottom_bndy () const

  Provides access to bottom boundary spatial coordinate.

- Real top_bndy () const

  Provides access to top boundary spatial coordinate.

- int num_cells_z () const

  Provides access to the number of cells of the grid.

- Real delta_z () const

  Provides access to the computed $ z $.

- bool Bound () const

  Have any field been bound to the grid?

- int Size () const

  Total number of samples in the grid.
- void BindScalarField (Real(∗ScalarField)(const Real &xx, const Real &yy, const Real &zz))

  Binds a given scalar field to the grid.
- void BindVectorField (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy, const Real &zz), Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy, const Real &zz), Real(∗VectorFieldR↩ Component)(const Real &xx, const Real &yy, const Real &zz))

  Binds a given vector field to the grid.
- bool WriteToFile (std::string filename, std::string space_name_x, std::string space_name_y, std::string space_↩ name_z, std::string field_name) const

  Writes grid to a file compatible with Gnuplot 4.6.

Private Member Functions

- void BindVectorFieldPComponent (Real(∗VectorFieldPComponent)(const Real &xx, const Real &yy, const Real &zz))

  Binds a given component of a vector field to the grid.
- void BindVectorFieldQComponent (Real(∗VectorFieldQComponent)(const Real &xx, const Real &yy, const Real &zz))

  Binds a given component of a vector field to the grid.
- void BindVectorFieldRComponent (Real(∗VectorFieldRComponent)(const Real &xx, const Real &yy, const Real &zz))

  Binds a given component of a vector field to the grid.

Private Attributes

- std::vector< Real > discrete_domain_x_

  Array of spatial data.
- std::vector< Real > discrete_domain_y_

  Array of spatial data.
- std::vector< Real > discrete_domain_z_

  Array of spatial data.
- std::vector< Real > discrete_field_

  Array of field's data.
- FieldNature nature_

  Nature of the discrete field.
- Real west_bndy_

  West boundary spatial coordinate.
- Real east_bndy_

  East boundary spatial coordinate.
- int num_cells_x_

  Number of cells discretizing the domain.
- Real delta_x_

  Computed Δx.
- 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 Δy.

- Real bottom_bndy_

  Bottom boundary spatial coordinate.

- Real top_bndy_

  Top boundary spatial coordinate.

- int num_cells_z_

  Number of cells discretizing the domain.

- Real delta_z_

  Computed Δz.

Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid3D &in)

  Prints the grid as a tuple of arrays.

17.25.1 Detailed Description

Uniform 3D Staggered Grid.

Definition at line 79 of file mtk_uni_stg_grid_3d.h.

17.25.2 Constructor & Destructor Documentation

17.25.2.1 mtk::UniStgGrid3D::UniStgGrid3D ( )

Definition at line 123 of file mtk_uni_stg_grid_3d.cc.

17.25.2.2 mtk::UniStgGrid3D::UniStgGrid3D (const UniStgGrid3D & *grid*)

Parameters

in	*grid*	Given grid.

Definition at line 142 of file mtk_uni_stg_grid_3d.cc.

17.25.2.3 mtk::UniStgGrid3D::UniStgGrid3D (const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const Real & *south_bndy_y*, const Real & *north_bndy_y*, const int & *num_cells_y*, const Real & *bottom_bndy_z*, const Real & *top_bndy_z*, const int & *num_cells_z*, const mtk::FieldNature & *nature* = mtk::FieldNature::SCALAR)

Parameters

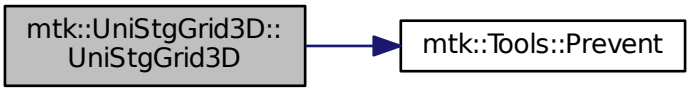
in	*west_bndy_x*	Coordinate for the west boundary.
in	*east_bndy_x*	Coordinate for the east boundary.
in	*num_cells_x*	Number of cells of the required grid.
in	*south_bndy_y*	Coordinate for the west boundary.
in	*north_bndy_y*	Coordinate for the east boundary.
in	*num_cells_y*	Number of cells of the required grid.
in	*bottom_bndy_z*	Coordinate for the bottom boundary.
in	*top_bndy_z*	Coordinate for the top boundary.
in	*num_cells_z*	Number of cells of the required grid.
in	*nature*	Nature of the discrete field to hold.

See also

mtk::FieldNature

Definition at line 174 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:



17.25.2.4 mtk::UniStgGrid3D::~UniStgGrid3D ( )

Definition at line 221 of file mtk_uni_stg_grid_3d.cc.

17.25.3 Member Function Documentation

17.25.3.1 void mtk::UniStgGrid3D::BindScalarField (Real(*)(const Real &xx, const Real &yy, const Real &zz) *ScalarField*)

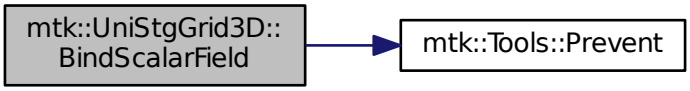
Parameters

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

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

Definition at line 318 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:



17.25.3.2 void mtk::UniStgGrid3D::BindVectorField (Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldPComponent*, Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldQComponent*, Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldRComponent*)

We assume the field to be of the form:

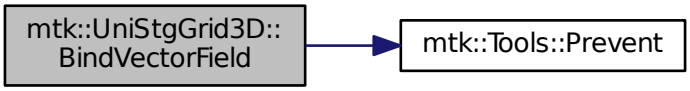
$$\mathbf{v}(\mathbf{x}) = p(x,y,z)\hat{\mathbf{i}} + q(x,y,z)\hat{\mathbf{j}} + r(x,y,z)\hat{\mathbf{k}}$$

Parameters

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

Definition at line 415 of file mtk_uni_stg_grid_3d.cc.

Here is the call graph for this function:



17.25.3.3 void mtk::UniStgGrid3D::BindVectorFieldPComponent (Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldPComponent*) [private]

We assume the field to be of the form:

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

Parameters

in	*BindVectorField↩ PComponent*	Pointer to the function implementing the $ p $ component of the vector field.

Definition at line 394 of file mtk_uni_stg_grid_3d.cc.

17.25.3.4 void mtk::UniStgGrid3D::BindVectorFieldQComponent (Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldQComponent*) [private]

We assume the field to be of the form:

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

Parameters

in	*BindVectorField↩ QComponent*	Pointer to the function implementing the $ q $ component of the vector field.

Definition at line 401 of file mtk_uni_stg_grid_3d.cc.

17.25.3.5 void mtk::UniStgGrid3D::BindVectorFieldRComponent (Real(∗)(const Real &xx, const Real &yy, const Real &zz) *VectorFieldRComponent*) [private]

We assume the field to be of the form:

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

Parameters

in	*BindVectorField↩ RComponent*	Pointer to the function implementing the $ r $ component of the vector field.

Definition at line 408 of file mtk_uni_stg_grid_3d.cc.

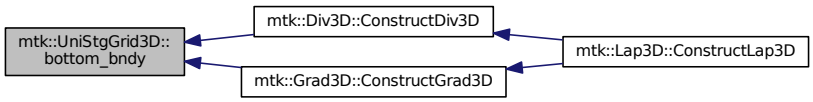
17.25.3.6 mtk::Real mtk::UniStgGrid3D::bottom_bndy ( ) const

Returns

Bottom boundary spatial coordinate.

Definition at line 278 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



17.25.3.7 bool mtk::UniStgGrid3D::Bound ( ) const

Returns

True is a field has been bound.

Definition at line 308 of file mtk_uni_stg_grid_3d.cc.

17.25.3.8 mtk::Real mtk::UniStgGrid3D::delta_x ( ) const

Returns

Computed $ x $.

Definition at line 243 of file mtk_uni_stg_grid_3d.cc.

17.25.3.9 mtk::Real mtk::UniStgGrid3D::delta_y ( ) const

Returns

Computed $ y $.

Definition at line 268 of file mtk_uni_stg_grid_3d.cc.

17.25.3.10 mtk::Real mtk::UniStgGrid3D::delta_z ( ) const

Returns

Computed $ z $.

Definition at line 293 of file mtk_uni_stg_grid_3d.cc.

17.25.3.11 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_x ( ) const

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 248 of file mtk_uni_stg_grid_3d.cc.

17.25.3.12 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_y ( ) const

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 273 of file mtk_uni_stg_grid_3d.cc.

17.25.3.13 const mtk::Real * mtk::UniStgGrid3D::discrete_domain_z ( ) const

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 298 of file mtk_uni_stg_grid_3d.cc.

17.25.3.14 mtk::Real * mtk::UniStgGrid3D::discrete_field ( )

Returns

Pointer to the field data.

Definition at line 303 of file mtk_uni_stg_grid_3d.cc.

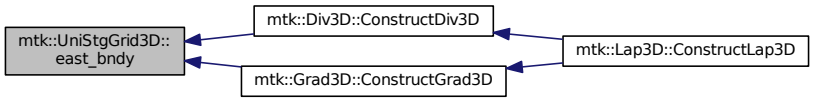
17.25.3.15 mtk::Real mtk::UniStgGrid3D::east_bndy ( ) const

Returns

East boundary spatial coordinate.

Definition at line 233 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



17.25.3.16 mtk::FieldNature mtk::UniStgGrid3D::nature ( ) const

Returns

Value of an enumeration.

See also

mtk::FieldNature

Definition at line 223 of file mtk_uni_stg_grid_3d.cc.

17.25.3.17 mtk::Real mtk::UniStgGrid3D::north_bndy ( ) const

Returns

North boundary spatial coordinate.

Definition at line 258 of file mtk_uni_stg_grid_3d.cc.

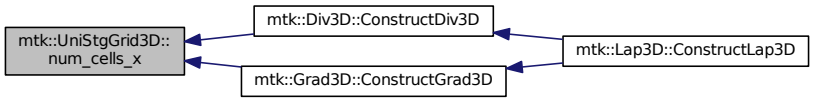
17.25.3.18 int mtk::UniStgGrid3D::num_cells_x ( ) const

Returns

Number of cells of the grid.

Definition at line 238 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



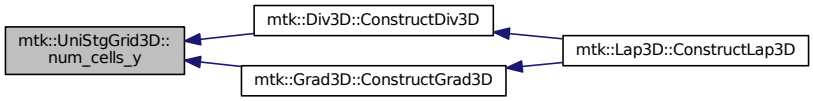
17.25.3.19 int mtk::UniStgGrid3D::num_cells_y ( ) const

Returns

Number of cells of the grid.

Definition at line 263 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



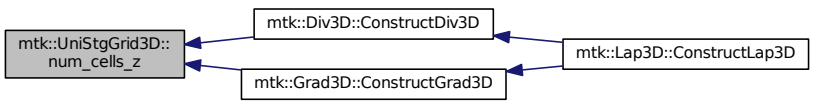
17.25.3.20 int mtk::UniStgGrid3D::num_cells_z ( ) const

Returns

Number of cells of the grid.

Definition at line 288 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



17.25.3.21 mtk::UniStgGrid3D mtk::UniStgGrid3D::operator= (const UniStgGrid3D & *in*)

Parameters

in	*in*	Given grid.

Returns

Copy of the given grid.

Definition at line 116 of file mtk_uni_stg_grid_3d.cc.

17.25.3.22 int mtk::UniStgGrid3D::Size ( ) const

Returns

Total number of samples in the grid.

Definition at line 313 of file mtk_uni_stg_grid_3d.cc.

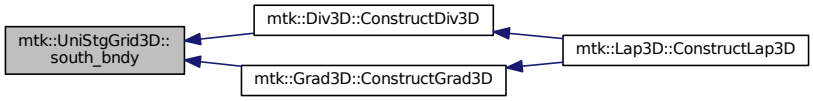
17.25.3.23 mtk::Real mtk::UniStgGrid3D::south_bndy ( ) const

Returns

South boundary spatial coordinate.

Definition at line 253 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



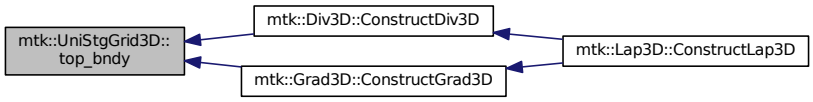
17.25.3.24 mtk::Real mtk::UniStgGrid3D::top_bndy ( ) const

Returns

Top boundary spatial coordinate.

Definition at line 283 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



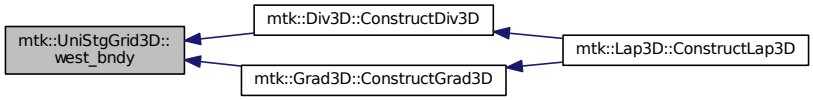
17.25.3.25 mtk::Real mtk::UniStgGrid3D::west_bndy ( ) const

Returns

West boundary spatial coordinate.

Definition at line 228 of file mtk_uni_stg_grid_3d.cc.

Here is the caller graph for this function:



17.25.3.26 bool mtk::UniStgGrid3D::WriteToFile (std::string *filename*, std::string *space_name_x*, std::string *space_name_y*, std::string *space_name_z*, std::string *field_name*) const

Parameters

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

Returns

Success of the file writing process.

See also

http://www.gnuplot.info/

Definition at line 435 of file mtk_uni_stg_grid_3d.cc.

17.25.4 Friends And Related Function Documentation

17.25.4.1 std::ostream& operator<< (std::ostream & *stream,* mtk::UniStgGrid3D & *in*) [friend]

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

Definition at line 67 of file mtk_uni_stg_grid_3d.cc.

17.25.5 Member Data Documentation

17.25.5.1 Real mtk::UniStgGrid3D::bottom_bndy_ [private]

Definition at line 396 of file mtk_uni_stg_grid_3d.h.

17.25.5.2 Real mtk::UniStgGrid3D::delta_x_ [private]

Definition at line 389 of file mtk_uni_stg_grid_3d.h.

17.25.5.3 Real mtk::UniStgGrid3D::delta_y_ [private]

Definition at line 394 of file mtk_uni_stg_grid_3d.h.

17.25.5.4 Real mtk::UniStgGrid3D::delta_z_ [private]

Definition at line 399 of file mtk_uni_stg_grid_3d.h.

17.25.5.5 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_x_ [private]

Definition at line 379 of file mtk_uni_stg_grid_3d.h.

17.25.5.6 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_y_ [private]

Definition at line 380 of file mtk_uni_stg_grid_3d.h.

17.25.5.7 std::vector<Real> mtk::UniStgGrid3D::discrete_domain_z_ [private]

Definition at line 381 of file mtk_uni_stg_grid_3d.h.

17.25.5.8 std::vector<Real> mtk::UniStgGrid3D::discrete_field_ [private]

Definition at line 382 of file mtk_uni_stg_grid_3d.h.

17.25.5.9 Real mtk::UniStgGrid3D::east_bndy_ [private]

Definition at line 387 of file mtk_uni_stg_grid_3d.h.

17.25.5.10 FieldNature mtk::UniStgGrid3D::nature_ [private]

Definition at line 384 of file mtk_uni_stg_grid_3d.h.

17.25.5.11 Real mtk::UniStgGrid3D::north_bndy_ [private]

Definition at line 392 of file mtk_uni_stg_grid_3d.h.

17.25.5.12 int mtk::UniStgGrid3D::num_cells_x_ [private]

Definition at line 388 of file mtk_uni_stg_grid_3d.h.

17.25.5.13 int mtk::UniStgGrid3D::num_cells_y_ [private]

Definition at line 393 of file mtk_uni_stg_grid_3d.h.

17.25.5.14 int mtk::UniStgGrid3D::num_cells_z_ [private]

Definition at line 398 of file mtk_uni_stg_grid_3d.h.

17.25.5.15 Real mtk::UniStgGrid3D::south_bndy_ [private]

Definition at line 391 of file mtk_uni_stg_grid_3d.h.

17.25.5.16 Real mtk::UniStgGrid3D::top_bndy_ [private]

Definition at line 397 of file mtk_uni_stg_grid_3d.h.

17.25.5.17 Real mtk::UniStgGrid3D::west_bndy_ [private]

Definition at line 386 of file mtk_uni_stg_grid_3d.h.

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

- include/mtk_uni_stg_grid_3d.h
- src/mtk_uni_stg_grid_3d.cc

Chapter 18

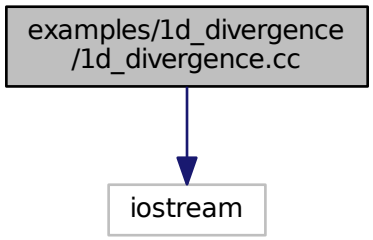
File Documentation

18.1 examples/1d_divergence/1d_divergence.cc File Reference

Creates instances of a 1D divergence as computed by the CBS algorithm.

```
#include <iostream>
```

Include dependency graph for 1d_divergence.cc:



Functions

- int main ()

18.1.1 Detailed Description

Author

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

Definition in file 1d_divergence.cc.

18.1.2 Function Documentation

18.1.2.1 int main ( )

Definition at line 102 of file 1d_divergence.cc.

18.2 1d_divergence.cc

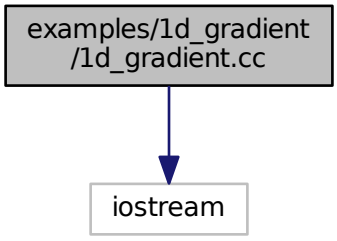
```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
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 <fstream>
00058 #include <cmath>
00059
00060 #include <string>
00061
00062 #include "mtk.h"
00063
00064 int main () {
00065
00066   std::cout << "Example: Instances of a 1D divergence as computed by the CBS "
00067     "algorithm." << std::endl;
00068
00070
00071   std::ofstream output_tex_file;
00072
00073   int max_order{14};
00074
```

```
00075   for (int order = 2; order <= max_order; order += 2) {
00076
00077     std::string output_tex_file_name{"div_1d_" + std::to_string(order) +
00078       ".tex"};
00079
00080     output_tex_file.open(output_tex_file_name);
00081
00082     mtk::Div1D div;
00083
00084     bool assertion = div.ConstructDiv1D(order);
00085     if (!assertion) {
00086       std::cerr << "Mimetic div (order" + std::to_string(order) +
00087         ") could not be built." <<        std::endl;
00088       return EXIT_FAILURE;
00089     }
00090
00091     output_tex_file << "\\begin{verbatim}" << std::endl;
00092     output_tex_file << div << std::endl;
00093     output_tex_file << "\\end{verbatim}" << std::endl;
00094     output_tex_file.close();
00095   }
00096 }
00097
00098 #else
00099 #include <iostream>
00100 using std::cout;
00101 using std::endl;
00102 int main () {
00103   cout << "This code HAS to be compiled with support for C++11." << endl;
00104   cout << "Exiting..." << endl;
00105   return EXIT_SUCCESS;
00106 }
00107 #endif
```

18.3 examples/1d_gradient/1d_gradient.cc File Reference

Creates instances of a 1D gradient as computed by the CBS algorithm.

`#include <iostream>`
Include dependency graph for 1d_gradient.cc:



Functions

- int main ()

18.3.1 Detailed Description

Author

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

Definition in file 1d_gradient.cc.

18.3.2 Function Documentation

18.3.2.1 int main ( )

Definition at line 102 of file 1d_gradient.cc.

18.4 1d_gradient.cc

```
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00008 /*
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00010 University. All rights reserved.
00011
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00013 are permitted provided that the following conditions are met:
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00028 4. Usage of the binary form on proprietary applications shall require explicit
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00030 be given to the copyright holders.
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00040 parties intellectual property rights.
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <fstream>
00058 #include <cmath>
00059
00060 #include <string>
```

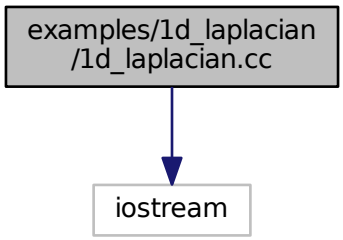
```
00061
00062 #include "mtk.h"
00063
00064 int main () {
00065
00066   std::cout << "Example: Instances of a 1D gradient as computed by the CBS "
00067     "algorithm." << std::endl;
00068
00070
00071   std::ofstream output_tex_file;
00072
00073   int max_order{14};
00074
00075   for (int order = 2; order <= max_order; order += 2) {
00076
00077     std::string output_tex_file_name{"grad_1d_" + std::to_string(order) +
00078       ".tex"};
00079
00080     output_tex_file.open(output_tex_file_name);
00081
00082     mtk::Grad1D grad;
00083
00084     bool assertion = grad.ConstructGrad1D(order);
00085     if (!assertion) {
00086       std::cerr << "Mimetic grad (order" + std::to_string(order) +
00087         ") could not be built." <<        std::endl;
00088       return EXIT_FAILURE;
00089     }
00090
00091     output_tex_file << "\\begin{verbatim}" << std::endl;
00092     output_tex_file << grad << std::endl;
00093     output_tex_file << "\\end{verbatim}" << std::endl;
00094     output_tex_file.close();
00095   }
00096 }
00097
00098 #else
00099 #include <iostream>
00100 using std::cout;
00101 using std::endl;
00102 int main () {
00103   cout << "This code HAS to be compiled with support for C++11." << endl;
00104   cout << "Exiting..." << endl;
00105   return EXIT_SUCCESS;
00106 }
00107 #endif
```

18.5 examples/1d_laplacian/1d_laplacian.cc File Reference

Creates instances of a 1D Laplacian as computed by the CBS algorithm.

```
#include <iostream>
```

Include dependency graph for 1d_laplacian.cc:



Functions

- int main ()

18.5.1 Detailed Description

Author

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

Definition in file 1d_laplacian.cc.

18.5.2 Function Documentation

18.5.2.1 int main ( )

Definition at line 102 of file 1d_laplacian.cc.

18.6 1d_laplacian.cc

```
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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
```

```
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00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
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00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
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00040 parties intellectual property rights.
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <fstream>
00058 #include <cmath>
00059
00060 #include <string>
00061
00062 #include "mtk.h"
00063
00064 int main () {
00065
00066   std::cout << "Example: Instances of a 1D Laplacian as computed by the CBS "
00067     "algorithm." << std::endl;
00068
00070
00071   std::ofstream output_tex_file;
00072
00073   int max_order{14};
00074
00075   for (int order = 2; order <= max_order; order += 2) {
00076
00077     std::string output_tex_file_name{"lap_1d_" + std::to_string(order) +
00078       ".tex"};
00079
00080     output_tex_file.open(output_tex_file_name);
00081
00082     mtk::Lap1D lap;
00083
00084     bool assertion = lap.ConstructLap1D(order);
00085     if (!assertion) {
00086       std::cerr << "Mimetic lap (order" + std::to_string(order) +
00087         ") could not be built." <<        std::endl;
00088       return EXIT_FAILURE;
00089     }
00090
00091     output_tex_file << "\\begin{verbatim}" << std::endl;
00092     output_tex_file << lap << std::endl;
00093     output_tex_file << "\\end{verbatim}" << std::endl;
00094     output_tex_file.close();
00095   }
00096 }
00097
00098 #else
00099 #include <iostream>
00100 using std::cout;
00101 using std::endl;
00102 int main () {
00103   cout << "This code HAS to be compiled with support for C++11." << endl;
00104   cout << "Exiting..." << endl;
00105   return EXIT_SUCCESS;
```

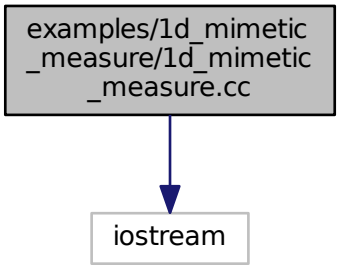
```
00106 }
00107 #endif
```

18.7 examples/1d_mimetic_measure/1d_mimetic_measure.cc File Reference

Compute the mimetic measure of different mimetic operators.

```
#include <iostream>
```

Include dependency graph for 1d_mimetic_measure.cc:



Functions

- int main ()

18.7.1 Detailed Description

Author

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

Definition in file 1d_mimetic_measure.cc.

18.7.2 Function Documentation

18.7.2.1 int main ( )

Definition at line 120 of file 1d_mimetic_measure.cc.

18.8 1d_mimetic_measure.cc

```
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00010 /*
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```

```
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00015 are permitted provided that the following conditions are met:
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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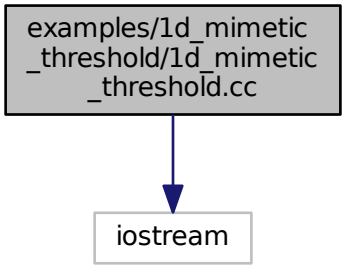
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <cmath>
00059
00060 #include <iostream>
00061 #include <fstream>
00062
00063 #include <array>
00064
00065 #include "mtk.h"
00066
00067 int main () {
00068
00069   std::cout << "Example: Computing the mimetic measure of gradient, "
00070     "divergence, and Laplacian operators." << std::endl;
00071
00072   const int max_order{14};
00073
00074   std::ofstream output_dat_file;  // Output file.
00075
00076   output_dat_file.open("mimetic_measure.tex");
00077
00078   if (!output_dat_file.is_open()) {
00079     std::cerr << "Could not open data file." << std::endl;
00080     return EXIT_FAILURE;
00081   }
00082
00083   output_dat_file << "\\begin{tabular}[c]{c:ccc}" << std::endl;
00084   output_dat_file << "\\toprule" << std::endl;
00085   output_dat_file << "$k$ & $\\mu(\\breve{\\mathbf{G}}^k_x)$ &"
00086     "$\\mu(\\breve{\\mathbf{D}}^k_x)$ & "
00087     "$\\mu(\\breve{\\mathbf{L}}^k_x)$ \\\\" << std::endl;
00088   output_dat_file << "\\midrule" << std::endl;
00089
00090   mtk::Grad1D grad;
00091   mtk::Div1D div;
00092   mtk::Lap1D lap;
00093
```

```
00094   for (int order = 2; order <= max_order; order += 2) {
00095
00096     bool go1{grad.ConstructGrad1D(order)};
00097     bool go2{div.ConstructDiv1D(order)};
00098     bool go3{lap.ConstructLap1D(order)};
00099
00100     if (go1 && go2 && go3) {
00101       output_dat_file << order << " & " << grad.mimetic_measure() << " & " <<
00102         div.mimetic_measure() << " & " << lap.mimetic_measure() << "\\\\" <<
00103         std::endl;
00104
00105     } else {
00106       std::cerr << "Mimetic operator could not be built." << std::endl;
00107       return EXIT_FAILURE;
00108     }
00109   }
00110
00111   output_dat_file << "\\bottomrule" << std::endl;
00112   output_dat_file << "\\end{tabular}" << std::endl;
00113
00114   output_dat_file.close();
00115 }
00116 #else
00117 #include <iostream>
00118 using std::cout;
00119 using std::endl;
00120 int main () {
00121   cout << "This code HAS to be compiled with support for C++11." << endl;
00122   cout << "Exiting..." << endl;
00123   return EXIT_SUCCESS;
00124 }
00125 #endif
```

18.9 examples/1d_mimetic_threshold/1d_mimetic_threshold.cc File Reference

Perform a sensitivity analysis of the mimetic threshold.

`#include <iostream>`
Include dependency graph for 1d_mimetic_threshold.cc:



Functions

- int main ()

18.9.1 Detailed Description

Author

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

Definition in file 1d_mimetic_threshold.cc.

18.9.2 Function Documentation

18.9.2.1 int main ( )

Definition at line 159 of file 1d_mimetic_threshold.cc.

18.10 1d_mimetic_threshold.cc

```
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00010 /*
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00012 University. All rights reserved.
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <cmath>
00059
00060 #include <iostream>
00061 #include <fstream>
00062
```

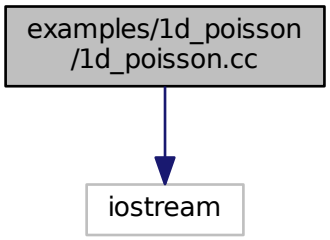
```
00063 #include <array>
00064
00065 #include "mtk.h"
00066
00067 int main () {
00068
00069   std::cout << "Example: Sensitivity analysis of the mimetic threshold when "
00070     "constructing 1D gradient and divergence operators." << std::endl;
00071
00072   std::array<int, 4> orders = {8, 10, 12, 14};
00073
00074   const int num_samples{10};
00075
00076   std::vector<mtk::Real> thresholds(num_samples);
00077
00078   thresholds.at(0) = 1e0;
00079   for (size_t ii = 1; ii < thresholds.size(); ++ii) {
00080     thresholds.at(ii) = thresholds.at(ii - 1)/10.0;
00081   }
00082
00083   std::array<mtk::Real, num_samples> num_feasible_sols{};
00084
00085   std::ofstream output_dat_file;  // Output file.
00086
00087   for (int kk: orders) {
00088
00089     output_dat_file.open("mimetic_threshold_div_" + std::to_string(kk) +
00090       ".dat");
00091
00092     if (!output_dat_file.is_open()) {
00093       std::cerr << "Could not open data file." << std::endl;
00094       return EXIT_FAILURE;
00095     }
00096
00097     output_dat_file << "# " << 'e' <<  ' ' << 'n' << std::endl;
00098
00099     for (size_t ii = 0; ii < thresholds.size(); ++ii) {
00100
00101       mtk::Real epsilon{thresholds.at(ii)};
00102
00103       mtk::Div1D div;
00104
00105       if (div.ConstructDiv1D(kk, epsilon)) {
00106         num_feasible_sols[ii] = div.num_feasible_sols();
00107       } else {
00108         std::cerr << "Mimetic divergence could not be built." << std::endl;
00109         return EXIT_FAILURE;
00110       }
00111     }
00112
00113     for (unsigned int ii = 0; ii < thresholds.size(); ++ii) {
00114       output_dat_file << thresholds[ii] << ' ' << num_feasible_sols[ii] <<
00115         std::endl;
00116     }
00117
00118     output_dat_file.close();
00119   }
00120
00121   for (int kk: orders) {
00122
00123     output_dat_file.open("mimetic_threshold_grad_" + std::to_string(kk) +
00124       ".dat");
00125
00126     if (!output_dat_file.is_open()) {
00127       std::cerr << "Could not open data file." << std::endl;
00128       return EXIT_FAILURE;
00129     }
00130
00131     output_dat_file << "# " << 'e' <<  ' ' << 'n' << std::endl;
00132
00133     for (size_t ii = 0; ii < thresholds.size(); ++ii) {
00134
00135       mtk::Real epsilon{thresholds.at(ii)};
00136
00137       mtk::Grad1D grad;
00138
00139       if (grad.ConstructGrad1D(kk, epsilon)) {
00140         num_feasible_sols[ii] = grad.num_feasible_sols();
00141       } else {
00142         std::cerr << "Mimetic gradient could not be built." << std::endl;
00143         return EXIT_FAILURE;
```

```
00144       }
00145     }
00146
00147     for (unsigned int ii = 0; ii < thresholds.size(); ++ii) {
00148       output_dat_file << thresholds[ii] << ' ' << num_feasible_sols[ii] <<
00149         std::endl;
00150     }
00151
00152     output_dat_file.close();
00153   }
00154 }
00155 #else
00156 #include <iostream>
00157 using std::cout;
00158 using std::endl;
00159 int main () {
00160   cout << "This code HAS to be compiled with support for C++11." << endl;
00161   cout << "Exiting..." << endl;
00162   return EXIT_SUCCESS;
00163 }
00164 #endif
```

18.11 examples/1d_poisson/1d_poisson.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`
Include dependency graph for 1d_poisson.cc:



Functions

- int main ()

18.11.1 Detailed Description

We solve:

$$-\nabla^2 p(x) = s(x),$$

for $x \in \Omega = [a,b] = [0,1]$.

The source term function is defined as:

$$s(x) = -\frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1},$$

where $\lambda = -1$ is a real-valued parameter.

We consider Robin's boundary conditions of the form:

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

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

where $\alpha = -\exp(\lambda)$, $\beta = \lambda^{-1}(\exp(\lambda) - 1.0)$, $\omega = -1$, and $\varepsilon = 0$.

The analytical solution for this problem is given by:

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

The mimetic counterpart of this equation is:

$$-\check{\mathbf{L}}_x^k \tilde{p} = \tilde{s}.$$

Finally, we will solve this problem considering $k = 2$.

Author

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

Definition in file 1d_poisson.cc.

18.11.2 Function Documentation

18.11.2.1 int main ( )

Definition at line 263 of file 1d_poisson.cc.

18.12 1d_poisson.cc

```
00001
00043 /*
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00046
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00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00065 be given to the copyright holders.
00066
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00070
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```

```
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00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #if __cplusplus == 201103L
00090
00091 #include <iostream>
00092 #include <fstream>
00093 #include <cmath>
00094
00095 #include <vector>
00096
00097 #include "mtk.h"
00098
00099 mtk::Real Alpha(const mtk::Real &tt) {
00100
00101   mtk::Real lambda{-1.0};
00102
00103   return -exp(lambda);
00104 }
00105
00106 mtk::Real Beta(const mtk::Real &tt) {
00107
00108   mtk::Real lambda{-1.0};
00109
00110   return (exp(lambda) - 1.0)/lambda;
00111 };
00112
00113 mtk::Real Omega(const mtk::Real &tt) {
00114
00115   return -1.0;
00116 };
00117
00118 mtk::Real Epsilon(const mtk::Real &tt) {
00119
00120   return 0.0;
00121 };
00122
00123 mtk::Real Source(const mtk::Real &xx) {
00124
00125   mtk::Real lambda{-1.0};
00126
00127   return -lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00128 }
00129
00130 mtk::Real KnownSolution(const mtk::Real &xx) {
00131
00132   mtk::Real lambda{-1.0};
00133
00134   return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00135 }
00136
00137 int main () {
00138
00139   std::cout << "Example: Poisson Equation with Robin BCs on a";
00140   std::cout << "1D Uniform Staggered Grid." << std::endl;
00141
00143   mtk::Real west_bndy_x{0.0};
00144   mtk::Real east_bndy_x{1.0};
00145   int num_cells_x{10};
00146
00147   mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00148
00150   mtk::Lap1D lap;
00151
00152   if (!lap.ConstructLap1D()) {
00153     std::cerr << "Mimetic Laplacian could not be built." << std::endl;
00154     return EXIT_FAILURE;
```

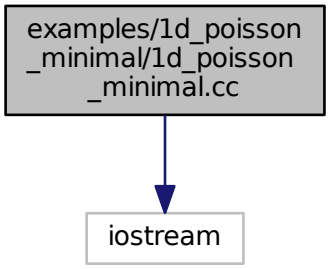
```
00155   }
00156
00157   std::cout << "lap=" << std::endl;
00158   std::cout << lap << std::endl;
00159
00160   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00161
00162   std::cout << "lapm =" << std::endl;
00163   std::cout << lapm << std::endl;
00164
00166
00167   lapm = mtk::BLASAdapter::RealDenseSM(-1.0, lapm);
00168
00169   std::cout << "-lapm =" << std::endl;
00170   std::cout << lapm << std::endl;
00171
00173   mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00174
00175   source.BindScalarField(Source);
00176
00177   std::cout << "source =" << std::endl;
00178   std::cout << source << std::endl;
00179
00181   mtk::RobinBCDescriptor1D robin_bc_desc_1d;
00182
00183   robin_bc_desc_1d.PushBackWestCoeff(Alpha);
00184   robin_bc_desc_1d.PushBackWestCoeff(Beta);
00185
00186   robin_bc_desc_1d.PushBackEastCoeff(Alpha);
00187   robin_bc_desc_1d.PushBackEastCoeff(Beta);
00188
00189   robin_bc_desc_1d.set_west_condition(Omega);
00190   robin_bc_desc_1d.set_east_condition(Epsilon);
00191
00192   if (!robin_bc_desc_1d.ImposeOnLaplacianMatrix(lap, lapm)) {
00193     std::cerr << "BCs  could not be bound to the matrix." << std::endl;
00194     return EXIT_FAILURE;
00195   }
00196
00197   std::cout << "Mimetic Laplacian operator with imposed BCs:" << std::endl;
00198   std::cout << lapm << std::endl;
00199
00200   if (!lapm.WriteToFile("1d_poisson_lapm.dat")) {
00201     std::cerr << "Laplacian matrix could not be written to disk." << std::endl;
00202     return EXIT_FAILURE;
00203   }
00204
00206   robin_bc_desc_1d.ImposeOnGrid(source);
00207
00208   std::cout << "source =" << std::endl;
00209   std::cout << source << std::endl;
00210
00211   if (!source.WriteToFile("1d_poisson_source.dat", "x", "s(x)")) {
00212     std::cerr << "Source term could not be written to disk." << std::endl;
00213     return EXIT_FAILURE;
00214   }
00215
00217   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00218
00219   if (!info) {
00220     std::cout << "System solved." << std::endl;
00221     std::cout << std::endl;
00222   } else {
00223     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00224     std::cerr << "Exiting..." << std::endl;
00225     return EXIT_FAILURE;
00226   }
00227
00228   std::cout << "Computed solution:" << std::endl;
00229   std::cout << source << std::endl;
00230
00231   if (!source.WriteToFile("1d_poisson_comp_sol.dat", "x", "~u(x)")) {
00232     std::cerr << "Solution could not be written to file." << std::endl;
00233     return EXIT_FAILURE;
00234   }
00235
00237   mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00238
00239   known_sol.BindScalarField(KnownSolution);
00240
00241   std::cout << "known_sol =" << std::endl;
```

```
00242   std::cout << known_sol << std::endl;
00243
00244   if (!known_sol.WriteToFile("1d_poisson_known_sol.dat", "x", "u(x)")) {
00245     std::cerr << "Known solution could not be written to file." << std::endl;
00246     return EXIT_FAILURE;
00247   }
00248
00249   mtk::Real relative_norm_2_error{};
00250
00251   relative_norm_2_error =
00252     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00253                                     known_sol.discrete_field(),
00254                                     known_sol.num_cells_x());
00255
00256   std::cout << "relative_norm_2_error = ";
00257   std::cout << relative_norm_2_error << std::endl;
00258 }
00259 #else
00260 #include <iostream>
00261 using std::cout;
00262 using std::endl;
00263 int main () {
00264   cout << "This code HAS to be compiled with support for C++11." << endl;
00265   cout << "Exiting..." << endl;
00266   return EXIT_SUCCESS;
00267 }
00268 #endif
```

18.13 examples/1d_poisson_minimal/1d_poisson_minimal.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`
Include dependency graph for 1d_poisson_minimal.cc:



Functions

- int main ()

18.13.1 Detailed Description

We solve:

$$-\nabla^2 p(x) = s(x),$$

for $x \in \Omega = [a,b] = [0,1]$.

The source term function is defined as:

$$s(x) = -\frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1},$$

where $\lambda = -1$ is a real-valued parameter.

We consider Robin's boundary conditions of the form:

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

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

where $\alpha = -\exp(\lambda)$, $\beta = (\exp(\lambda) - 1.0)/\lambda$, $\omega = -1$, and $\varepsilon = 0$.

The analytical solution for this problem is given by:

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

The mimetic counterpart of this equation is:

$$-\check{\mathbf{L}}_x^k \tilde{p} = \tilde{s}.$$

Finally, we will solve this problem considering $k = 2$.

Author

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

Definition in file 1d_poisson_minimal.cc.

18.13.2 Function Documentation

18.13.2.1 int main ( )

Definition at line 164 of file 1d_poisson_minimal.cc.

18.14 1d_poisson_minimal.cc

```
00001
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00045 University. All rights reserved.
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00048 are permitted provided that the following conditions are met:
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00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00059 3. Redistributions in binary form must reproduce the above copyright notice,
00060 this list of conditions and the following disclaimer in the documentation and/or
00061 other materials provided with the distribution.
00062
00063 4. Usage of the binary form on proprietary applications shall require explicit
00064 prior written permission from the the copyright holders, and due credit should
```

```
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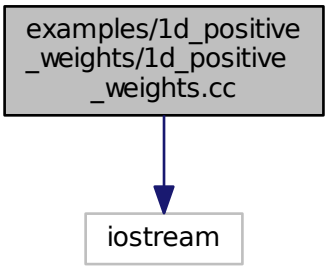
00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #if __cplusplus == 201103L
00090
00091 #include <iostream>
00092 #include <fstream>
00093 #include <cmath>
00094 #include <vector>
00095
00096 #include "mtk.h"
00097
00098 mtk::Real Alpha(const mtk::Real &tt) {
00099   mtk::Real lambda = -1.0;
00100   return -exp(lambda);
00101 }
00102
00103 mtk::Real Beta(const mtk::Real &tt) {
00104   mtk::Real lambda = -1.0;
00105   return (exp(lambda) - 1.0)/lambda;
00106 };
00107
00108 mtk::Real Omega(const mtk::Real &tt) { return -1.0; };
00109
00110 mtk::Real Epsilon(const mtk::Real &tt) { return 0.0; };
00111
00112 mtk::Real Source(const mtk::Real &xx) {
00113   mtk::Real lambda = -1.0;
00114   return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00115 }
00116
00117 mtk::Real KnownSolution(const mtk::Real &xx) {
00118   mtk::Real lambda = -1.0;
00119   return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00120 }
00121
00122 int main () {
00123
00124   mtk::Real west_bndy_x{};
00125   mtk::Real east_bndy_x{1.0};
00126   int num_cells_x{5};
00127   mtk::Lap1D lap;
00128   if (!lap.ConstructLap1D()) {
00129     return EXIT_FAILURE;
00130   }
00131   mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00132   mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00133   mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00134   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00135   source.BindScalarField(Source);
00136   mtk::RobinBCDescriptor1D bcs;
00137   bcs.PushBackWestCoeff(Alpha);
00138   bcs.PushBackWestCoeff(Beta);
00139   bcs.PushBackEastCoeff(Alpha);
00140   bcs.PushBackEastCoeff(Beta);
00141   bcs.set_west_condition(Omega);
00142   bcs.set_east_condition(Epsilon);
00143   if (!bcs.ImposeOnLaplacianMatrix(lap, lapm)) {
00144     return EXIT_FAILURE;
00145   }
```

```
00146   bcs.ImposeOnGrid(source);
00147   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00148   if (info != 0) {
00149     return EXIT_FAILURE;
00150   }
00151   source.WriteToFile("1d_poisson_minimal_comp_sol.dat", "x", "~u(x)");
00152   known_sol.BindScalarField(KnownSolution);
00153   known_sol.WriteToFile("1d_poisson_minimal_known_sol.dat", "x", "u(x)");
00154   mtk::Real relative_norm_2_error =
00155     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00156                                     known_sol.discrete_field(),
00157                                     known_sol.num_cells_x());
00158   std::cout << relative_norm_2_error << std::endl;
00159 }
00160 #else
00161 #include <iostream>
00162 using std::cout;
00163 using std::endl;
00164 int main () {
00165   cout << "This code HAS to be compiled with support for C++11." << endl;
00166   cout << "Exiting..." << endl;
00167   return EXIT_SUCCESS;
00168 }
00169 #endif
```

18.15 examples/1d_positive_weights/1d_positive_weights.cc File Reference

The CBS algorithm computes positive-definite weights, for 1D operators.

`#include <iostream>`
Include dependency graph for 1d_positive_weights.cc:



Functions

- int main ()

18.15.1 Detailed Description

Author

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

Definition in file 1d_positive_weights.cc.

18.15.2 Function Documentation

18.15.2.1 int main ( )

Definition at line 134 of file 1d_positive_weights.cc.

18.16 1d_positive_weights.cc

```
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00008 /*
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
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00026 other materials provided with the distribution.
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <fstream>
00058 #include <cmath>
00059
00060 #include <vector>
00061
00062 #include "mtk.h"
00063
00064 int main () {
00065
00066   std::cout << "Example: Positive-Definite Weights for 1D Mimetic"
00067     "Operators." << std::endl;
00068
00070
00071   mtk::Grad1D grad10;
00072
00073   bool assertion = grad10.ConstructGrad1D(10);
00074   if (!assertion) {
```

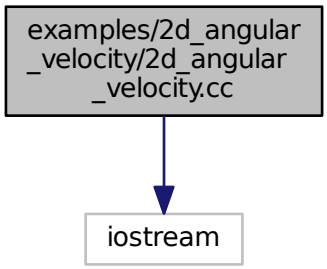
```
00075     std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00076     return EXIT_FAILURE;
00077   }
00078
00079   mtk::Grad1D grad12;
00080
00081   assertion = grad12.ConstructGrad1D(12);
00082   if (!assertion) {
00083     std::cerr << "Mimetic grad (12th order) could not be built." << std::endl;
00084     return EXIT_FAILURE;
00085   }
00086
00087   mtk::Grad1D grad14;
00088
00089   assertion = grad14.ConstructGrad1D(14);
00090   if (!assertion) {
00091     std::cerr << "Mimetic grad (14th order) could not be built." << std::endl;
00092     return EXIT_FAILURE;
00093   }
00094
00096
00097   mtk::Div1D div8;
00098
00099   assertion = div8.ConstructDiv1D(8);
00100   if (!assertion) {
00101     std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00102     return EXIT_FAILURE;
00103   }
00104
00105   mtk::Div1D div10;
00106
00107   assertion = div10.ConstructDiv1D(10);
00108   if (!assertion) {
00109     std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00110     return EXIT_FAILURE;
00111   }
00112
00113   mtk::Div1D div12;
00114
00115   assertion = div12.ConstructDiv1D(12);
00116   if (!assertion) {
00117     std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00118     return EXIT_FAILURE;
00119   }
00120
00121   mtk::Div1D div14;
00122
00123   assertion = div14.ConstructDiv1D(14);
00124   if (!assertion) {
00125     std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00126     return EXIT_FAILURE;
00127   }
00128 }
00129
00130 #else
00131 #include <iostream>
00132 using std::cout;
00133 using std::endl;
00134 int main () {
00135   cout << "This code HAS to be compiled with support for C++11." << endl;
00136   cout << "Exiting..." << endl;
00137   return EXIT_SUCCESS;
00138 }
00139 #endif
```

18.17 examples/2d_angular_velocity/2d_angular_velocity.cc File Reference

Compute the curl of a 2D angular velocity field.

```
#include <iostream>
```

Include dependency graph for 2d_angular_velocity.cc:



Functions

- int main ()

18.17.1 Detailed Description

We compute the curl of:

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

Author

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

Definition in file 2d_angular_velocity.cc.

18.17.2 Function Documentation

18.17.2.1 int main ( )

Definition at line 106 of file 2d_angular_velocity.cc.

18.18 2d_angular_velocity.cc

```
00001
00013 /*
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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
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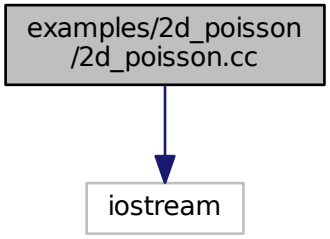
00053 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #if __cplusplus == 201103L
00060
00061 #include <iostream>
00062 #include <fstream>
00063 #include <cmath>
00064
00065 #include <vector>
00066
00067 #include "mtk.h"
00068
00069 mtk::Real VectorFieldPComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00070
00071   return -yy;
00072 }
00073
00074 mtk::Real VectorFieldQComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00075
00076   return xx;
00077 }
00078
00079 int main () {
00080
00081   std::cout << "Example: Curl of a angular velocity field." << std::endl;
00082
00084   mtk::Real aa = 0.0;
00085   mtk::Real bb = 4.0;
00086   mtk::Real cc = 0.0;
00087   mtk::Real dd = 4.0;
00088
00089   int nn = 10;
00090   int mm = 10;
00091
00092   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm,
      mtk::FieldNature::VECTOR);
00093
00094   gg.BindVectorField(VectorFieldPComponent, VectorFieldQComponent);
00095
00096   if(!gg.WriteToFile("2d_angular_velocity_gg.dat", "x", "y", "v(x,y)")) {
00097     std::cerr << "Angular field could not be written to disk." << std::endl;
00098     return EXIT_FAILURE;
00099   }
00100 }
```

```
00101
00102 #else
00103 #include <iostream>
00104 using std::cout;
00105 using std::endl;
00106 int main () {
00107   cout << "This code HAS to be compiled with support for C++11." << endl;
00108   cout << "Exiting..." << endl;
00109   return EXIT_SUCCESS;
00110 }
00111 #endif
```

18.19 examples/2d_poisson/2d_poisson.cc File Reference

Poisson Equation on a 2D Uniform Staggered Grid with Robin BCs.

`#include <iostream>`
Include dependency graph for 2d_poisson.cc:



Functions

- int main ()

18.19.1 Detailed Description

We solve:

$$\nabla^2 u(\mathbf{x}) = s(\mathbf{x}),$$

for $\mathbf{x} \in \Omega = [0,1]^2$.

The source term function is defined as

$$s(x,y) = xye^{-0.5(x^2+y^2)}(x^2+y^2-6).$$

Let $\partial\Omega = S \cup N \cup W \cup E$. We consider Dirichlet boundary conditions of the following form:

$$\forall \mathbf{x} \in W : u(\mathbf{x}) = 0.$$

$$\forall \mathbf{x} \in E : u(1,y) = -e^{-0.5(1-y^2)}(1-y^2).$$

$$\forall \mathbf{x} \in S : u(\mathbf{x}) = 0.$$

$$\forall \mathbf{x} \in N : u(x,1) = -e^{-0.5(x^2-1)}(x^2-1).$$

The analytical solution for this problem is given by

$$u(x,y) = xye^{-0.5(x^2+y^2)}.$$

Author

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

Definition in file 2d_poisson.cc.

18.19.2 Function Documentation

18.19.2.1 int main ( )

Definition at line 241 of file 2d_poisson.cc.

18.20 2d_poisson.cc

```
00001
00039 /*
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00041 University. All rights reserved.
00042
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00044 are permitted provided that the following conditions are met:
00045
00046 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00047 and a copy of the modified files should be reported once modifications are
00048 completed, unless these modifications are made through the project's GitHub
00049 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00050 should be developed and included in any deliverable.
00051
00052 2. Redistributions of source code must be done through direct
00053 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00054
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00080 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00081 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00082 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00083 */
00084
```

```
00085 #if __cplusplus == 201103L
00086
00087 #include <iostream>
00088 #include <fstream>
00089 #include <cmath>
00090
00091 #include <vector>
00092
00093 #include "mtk.h"
00094
00095 mtk::Real Source(const mtk::Real &xx, const mtk::Real &yy) {
00096
00097   mtk::Real x_squared{xx*xx};
00098   mtk::Real y_squared{yy*yy};
00099   mtk::Real aux{-0.5*(x_squared + y_squared)};
00100
00101   return xx*yy*exp(aux)*(x_squared + y_squared - 6.0);
00102 }
00103
00104 mtk::Real BCCoeff(const mtk::Real &xx, const mtk::Real &yy) {
00105
00106   return mtk::kOne;
00107 }
00108
00109 mtk::Real WestBC(const mtk::Real &xx, const mtk::Real &tt) {
00110
00111   return mtk::kZero;
00112 }
00113
00114 mtk::Real EastBC(const mtk::Real &yy, const mtk::Real &tt) {
00115
00116   return yy*exp(-0.5*(mtk::kOne + yy*yy));
00117 }
00118
00119 mtk::Real SouthBC(const mtk::Real &xx, const mtk::Real &tt) {
00120
00121   return mtk::kZero;
00122 }
00123
00124 mtk::Real NorthBC(const mtk::Real &xx, const mtk::Real &tt) {
00125
00126   return xx*exp(-0.5*(xx*xx + mtk::kOne));
00127 }
00128
00129 mtk::Real KnownSolution(const mtk::Real &xx, const mtk::Real &yy) {
00130
00131   mtk::Real x_squared{xx*xx};
00132   mtk::Real y_squared{yy*yy};
00133   mtk::Real aux{-0.5*(x_squared + y_squared)};
00134
00135   return xx*yy*exp(aux);
00136 }
00137
00138 int main () {
00139
00140   std::cout << "Example: Poisson Equation on a 2D Uniform Staggered Grid ";
00141   std::cout << "with Dirichlet and Neumann BCs." << std::endl;
00142
00144   mtk::Real west_bndy_x{0.0};
00145   mtk::Real east_bndy_x{1.0};
00146   mtk::Real south_bndy_y{0.0};
00147   mtk::Real north_bndy_y{1.0};
00148   int num_cells_x{5};
00149   int num_cells_y{5};
00150
00151   mtk::UniStgGrid2D comp_sol(west_bndy_x, east_bndy_x, num_cells_x,
00152                              south_bndy_y, north_bndy_y, num_cells_y);
00153
00155   mtk::Lap2D lap;
00156
00157   if (!lap.ConstructLap2D(comp_sol)) {
00158     std::cerr << "Mimetic Laplacian could not be built." << std::endl;
00159     return EXIT_FAILURE;
00160   }
00161
00162   mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix());
00163
00165   mtk::UniStgGrid2D source(west_bndy_x, east_bndy_x, num_cells_x,
00166                            south_bndy_y, north_bndy_y, num_cells_y);
00167
00168   source.BindScalarField(Source);
```

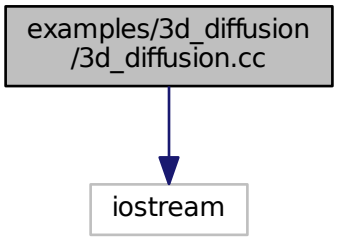
```
00169
00171   mtk::RobinBCDescriptor2D bcd;
00172
00173   bcd.PushBackWestCoeff(BCCoeff);
00174   bcd.PushBackEastCoeff(BCCoeff);
00175   bcd.PushBackSouthCoeff(BCCoeff);
00176   bcd.PushBackNorthCoeff(BCCoeff);
00177
00178   bcd.ImposeOnLaplacianMatrix(lap, comp_sol, lapm);
00179
00180   if (!lapm.WriteToFile("2d_poisson_lapm.dat")) {
00181     std::cerr << "Laplacian matrix could not be written to disk." << std::endl;
00182     return EXIT_FAILURE;
00183   }
00184
00186   bcd.set_west_condition(WestBC);
00187   bcd.set_east_condition(EastBC);
00188   bcd.set_south_condition(SouthBC);
00189   bcd.set_north_condition(NorthBC);
00190
00191   bcd.ImposeOnGrid(source);
00192
00193   if(!source.WriteToFile("2d_poisson_source.dat", "x", "y", "s(x,y)")) {
00194     std::cerr << "Source term could not be written to disk." << std::endl;
00195     return EXIT_FAILURE;
00196   }
00197
00199   int info{mtk::LAPACKAdapter::SolveDenseSystem(lapm, source)};
00200
00201   if (!info) {
00202     std::cout << "System solved." << std::endl;
00203     std::cout << std::endl;
00204   } else {
00205     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00206     std::cerr << "Exiting..." << std::endl;
00207     return EXIT_FAILURE;
00208   }
00209
00210   if (!source.WriteToFile("2d_poisson_comp_sol.dat", "x", "y", "~u(x,y)")) {
00211     std::cerr << "Solution could not be written to file." << std::endl;
00212     return EXIT_FAILURE;
00213   }
00214
00216   mtk::UniStgGrid2D known_sol(west_bndy_x, east_bndy_x, num_cells_x,
00217                               south_bndy_y, north_bndy_y, num_cells_y);
00218
00219   known_sol.BindScalarField(KnownSolution);
00220
00221   if (!known_sol.WriteToFile("2d_poisson_known_sol.dat", "x", "y", "u(x,y)")) {
00222     std::cerr << "Known solution could not be written to file." << std::endl;
00223     return EXIT_FAILURE;
00224   }
00225
00226   mtk::Real relative_norm_2_error{};
00227
00228   relative_norm_2_error =
00229     mtk::BLASAdapter::RelNorm2Error(source.discrete_field(),
00230                                     known_sol.discrete_field(),
00231                                     known_sol.Size());
00232
00233   std::cout << "relative_norm_2_error = ";
00234   std::cout << relative_norm_2_error << std::endl;
00235 }
00236
00237 #else
00238 #include <iostream>
00239 using std::cout;
00240 using std::endl;
00241 int main () {
00242   cout << "This code HAS to be compiled with support for C++11." << endl;
00243   cout << "Exiting..." << endl;
00244   return EXIT_SUCCESS;
00245 }
00246 #endif
```

18.21 examples/3d_diffusion/3d_diffusion.cc File Reference

Diffusion Equation on a 3D Uniform Staggered Grid with Dirichlet BCs.

```
#include <iostream>
```

Include dependency graph for 3d_diffusion.cc:



Functions

- int main ()

18.21.1 Detailed Description

We solve:

$$\frac{\partial u}{\partial t} = \nabla^2 u(\mathbf{x}),$$

for $\mathbf{x} \in \Omega = [0,1]^3$.

We consider autonomous homogeneous Dirichlet boundary conditions.

Author

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

Definition in file 3d_diffusion.cc.

18.21.2 Function Documentation

18.21.2.1 int main ( )

Definition at line 123 of file 3d_diffusion.cc.

18.22 3d_diffusion.cc

```
00001
```

```
00016 /*
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00018 University. All rights reserved.
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00021 are permitted provided that the following conditions are met:
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00024 and a copy of the modified files should be reported once modifications are
00025 completed, unless these modifications are made through the project's GitHub
00026 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00027 should be developed and included in any deliverable.
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00030 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00057 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00058 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00059 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00060 */
00061
00062 #if __cplusplus == 201103L
00063
00064 #include <iostream>
00065 #include <fstream>
00066 #include <cmath>
00067
00068 #include <vector>
00069
00070 #include "mtk.h"
00071
00072 mtk::Real InitialCondition(const mtk::Real &xx,
00073                            const mtk::Real &yy,
00074                            const mtk::Real &zz) {
00075
00076   mtk::Real rr{0.3};
00077
00078   mtk::Real aux{xx*xx + yy*yy + zz*zz};
00079
00080   return (aux < rr? rr - aux: mtk::kZero);
00081 }
00082
00083 int main () {
00084
00085   std::cout << "Example: Diffusion Equation in 3D "
00086     "with Dirichlet BCs." << std::endl;
00087
00089   mtk::Real west_bndy_x{0.0};
00090   mtk::Real east_bndy_x{1.0};
00091   mtk::Real south_bndy_y{0.0};
00092   mtk::Real north_bndy_y{1.0};
00093   mtk::Real bottom_bndy_z{0.0};
00094   mtk::Real top_bndy_z{1.0};
00095
00096   int num_cells_x{50};
00097   int num_cells_y{50};
```

```
00098   int num_cells_z{50};
00099
00100   mtk::UniStgGrid3D comp_sol(west_bndy_x, east_bndy_x, num_cells_x,
00101                              south_bndy_y, north_bndy_y, num_cells_y,
00102                              bottom_bndy_z, top_bndy_z, num_cells_z);
00103
00105   comp_sol.BindScalarField(InitialCondition);
00106
00107   if(!comp_sol.WriteToFile("3d_diffusion_comp_sol.dat",
00108                            "x",
00109                            "y",
00110                            "z",
00111                            "Initial u(x,y,z)")) {
00112     std::cerr << "Error writing to file." << std::endl;
00113     return EXIT_FAILURE;
00114   }
00115
00117 }
00118
00119 #else
00120 #include <iostream>
00121 using std::cout;
00122 using std::endl;
00123 int main () {
00124   cout << "This code HAS to be compiled with support for C++11." << endl;
00125   cout << "Exiting..." << endl;
00126   return EXIT_SUCCESS;
00127 }
00128 #endif
```

18.23 include/mtk.h File Reference

Includes the entire API.

```
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_tools.h"
#include "mtk_matrix.h"
#include "mtk_dense_matrix.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_uni_stg_grid_2d.h"
#include "mtk_uni_stg_grid_3d.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
#include "mtk_robin_bc_descriptor_1d.h"
#include "mtk_quad_1d.h"
#include "mtk_interp_1d.h"
#include "mtk_grad_2d.h"
#include "mtk_div_2d.h"
#include "mtk_curl_2d.h"
#include "mtk_lap_2d.h"
#include "mtk_robin_bc_descriptor_2d.h"
#include "mtk_grad_3d.h"
#include "mtk_div_3d.h"
#include "mtk_lap_3d.h"
#include "mtk_robin_bc_descriptor_3d.h"
```

Include dependency graph for mtk.h:

18.23.1 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.

18.24 mtk.h

```
00001
00015 /*
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00017 University. All rights reserved.
00018
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00020 are permitted provided that the following conditions are met:
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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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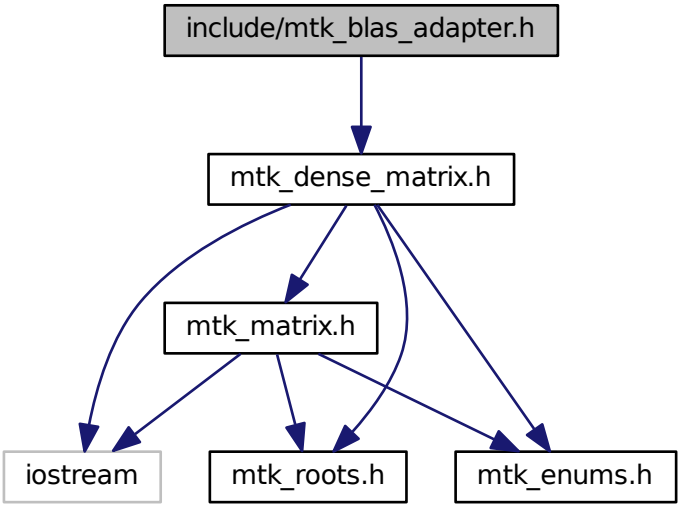
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00277 #ifndef MTK_INCLUDE_MTK_H_
00278 #define MTK_INCLUDE_MTK_H_
00279
00287 #include "mtk_roots.h"
00288
00296 #include "mtk_enums.h"
00297
00305 #include "mtk_tools.h"
00306
00314 #include "mtk_matrix.h"
00315 #include "mtk_dense_matrix.h"
00316
00324 #include "mtk_blas_adapter.h"
00325 #include "mtk_lapack_adapter.h"
00326 #include "mtk_glpk_adapter.h"
00327
00335 #include "mtk_uni_stg_grid_1d.h"
00336 #include "mtk_uni_stg_grid_2d.h"
00337 #include "mtk_uni_stg_grid_3d.h"
00338
00346 #include "mtk_grad_1d.h"
00347 #include "mtk_div_1d.h"
00348 #include "mtk_lap_1d.h"
00349 #include "mtk_robin_bc_descriptor_1d.h"
00350 #include "mtk_quad_1d.h"
00351 #include "mtk_interp_1d.h"
00352
00353 #include "mtk_grad_2d.h"
00354 #include "mtk_div_2d.h"
00355 #include "mtk_curl_2d.h"
00356 #include "mtk_lap_2d.h"
00357 #include "mtk_robin_bc_descriptor_2d.h"
00358
00359 #include "mtk_grad_3d.h"
00360 #include "mtk_div_3d.h"
00361 #include "mtk_lap_3d.h"
00362 #include "mtk_robin_bc_descriptor_3d.h"
00363
00364 #endif // End of: MTK_INCLUDE_MTK_H_
```

18.25 include/mtk_blas_adapter.h File Reference

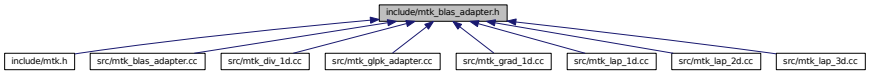
Adapter class for the BLAS API.

```
#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.

18.25.1 Detailed Description

Definition of a class that contains a collection of static member functions, 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.

18.26 mtk_blas_adapter.h

```
00001
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00033 and a copy of the modified files should be reported once modifications are
00034 completed, unless these modifications are made through the project's GitHub
00035 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00036 should be developed and included in any deliverable.
00037
00038 2. Redistributions of source code must be done through direct
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00066 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00067 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00068 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00069 */
00070
00071 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00072 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00073
00074 #include "mtk_dense_matrix.h"
```

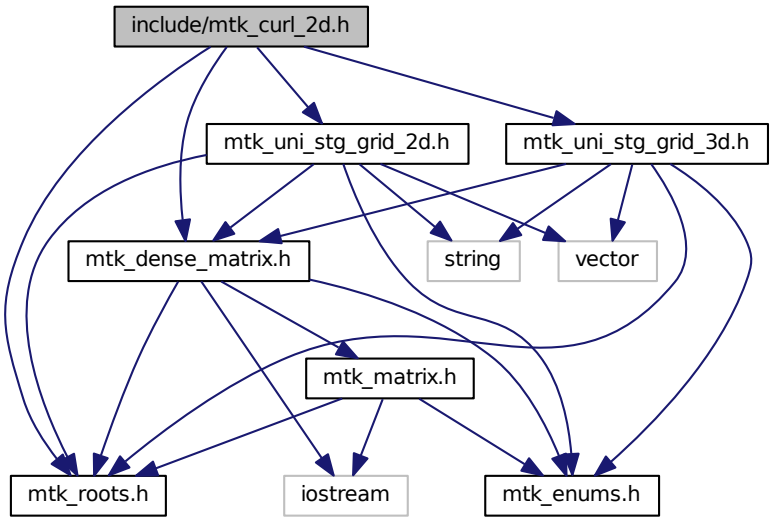
```
00075
00076 namespace mtk {
00077
00099 class BLASAdapter {
00100  public:
00109   static Real RealNRM2(Real *in, int &in_length);
00110
00127   static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00128
00143   static Real RelNorm2Error(Real *computed, Real *known, int length);
00144
00162   static void RealDenseMV(Real &alpha,
00163                           DenseMatrix &aa,
00164                           Real *xx,
00165                           Real &beta,
00166                           Real *yy);
00167
00182   static DenseMatrix RealDenseMM(DenseMatrix &aa,
      DenseMatrix &bb);
00183
00198   static DenseMatrix RealDenseSM(Real alpha,
      DenseMatrix &aa);
00199 };
00200 }
00201 #endif  // End of: MTK_INCLUDE_BLAS_ADAPTER_H_
```

18.27 include/mtk_curl_2d.h File Reference

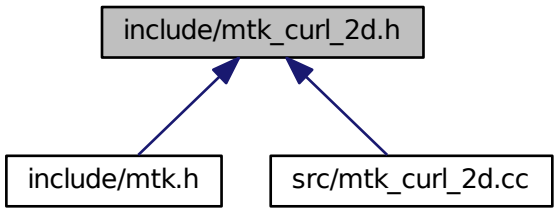
Includes the definition of the class Curl2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_curl_2d.h:



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



Classes

- class mtk::Curl2D

  Implements a 2D mimetic curl operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.27.1 Detailed Description

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

Author

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

Definition in file mtk_curl_2d.h.

18.28 mtk_curl_2d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
```

```
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00028 this list of conditions and the following disclaimer in the documentation and/or
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00030
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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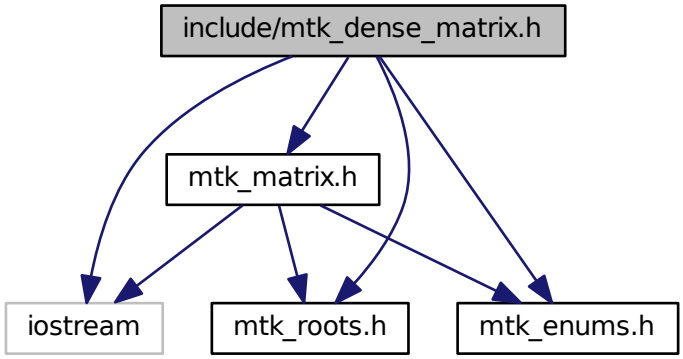
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_CURL_2D_H_
00058 #define MTK_INCLUDE_MTK_CURL_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063 #include "mtk_uni_stg_grid_3d.h"
00064
00065 namespace mtk{
00066
00077 class Curl2D {
00078  public:
00080   UniStgGrid3D operator*(const UniStgGrid2D &grid) const;
00081
00083   Curl2D();
00084
00090   Curl2D(const Curl2D &curl);
00091
00093   ~Curl2D();
00094
00100   bool ConstructCurl2D(const UniStgGrid2D &grid,
00101                        int order_accuracy = kDefaultOrderAccuracy,
00102                        Real mimetic_threshold = kDefaultMimeticThreshold);
00103
00109   DenseMatrix ReturnAsDenseMatrix() const;
00110
00111  private:
00112   DenseMatrix curl_;
00113
00114   int order_accuracy_;
00115
00116   Real mimetic_threshold_;
00117 };
00118 }
00119 #endif  // End of: MTK_INCLUDE_MTK_CURL_2D_H_
```

18.29 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.

18.29.1 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.

18.30 mtk_dense_matrix.h

```
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00023 /*
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00031 and a copy of the modified files should be reported once modifications are
00032 completed, unless these modifications are made through the project's GitHub
00033 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00034 should be developed and included in any deliverable.
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00064 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00065 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00066 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00067 */
00068
00069 #ifndef MTK_INCLUDE_DENSE_MATRIX_H_
00070 #define MTK_INCLUDE_DENSE_MATRIX_H_
00071
00072 #include <iostream>
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_enums.h"
00076 #include "mtk_matrix.h"
00077
00078 namespace mtk {
00079
00092 class DenseMatrix {
00093  public:
```

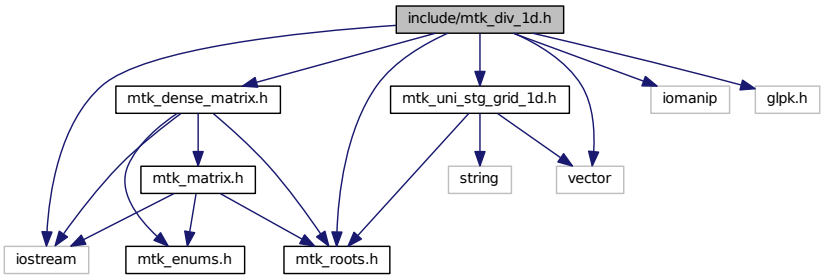
```
00095   friend std::ostream& operator <<(std::ostream &stream, DenseMatrix &in);
00096
00104   DenseMatrix& operator =(const DenseMatrix &in);
00105
00107   bool operator ==(const DenseMatrix &in);
00108
00110   DenseMatrix();
00111
00117   DenseMatrix(const DenseMatrix &in);
00118
00127   DenseMatrix(const int &num_rows, const int &num_cols);
00128
00154   DenseMatrix(const int &rank, const bool &padded, const bool &transpose);
00155
00189   DenseMatrix(const Real *const gen,
00190               const int &gen_length,
00191               const int &pro_length,
00192               const bool &transpose);
00193
00195   ~DenseMatrix();
00196
00202   Matrix matrix_properties() const noexcept;
00203
00209   int num_rows() const noexcept;
00210
00216   int num_cols() const noexcept;
00217
00223   Real* data() const noexcept;
00224
00232   void SetOrdering(mtk::MatrixOrdering oo) noexcept;
00233
00242   Real GetValue(const int &row_coord, const int &col_coord) const noexcept;
00243
00251   void SetValue(const int &row_coord,
00252                 const int &col_coord,
00253                 const Real &val) noexcept;
00254
00256   void Transpose();
00257
00259   void OrderRowMajor();
00260
00262   void OrderColMajor();
00263
00274   static DenseMatrix Kron(const DenseMatrix &aa,
00275                           const DenseMatrix &bb);
00276
00286   bool WriteToFile(const std::string &filename) const;
00287
00288  private:
00289   Matrix matrix_properties_;
00290
00291   Real *data_;
00292 };
00293 }
00294 #endif  // End of: MTK_INCLUDE_MTK_DENSE_MATRIX_H_
```

18.31 include/mtk_div_1d.h File Reference

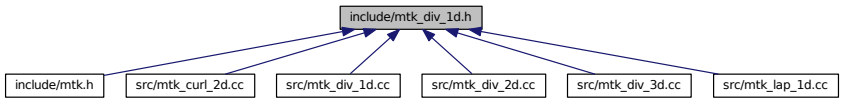
Includes the definition of the class Div1D.

```
#include <iostream>
#include <iomanip>
#include <vector>
#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.

18.31.1 Detailed Description

Definition of a class that 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.

18.32 mtk_div_1d.h

```
00001
```

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00055 */
00056
00057 #ifndef MTK_INCLUDE_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include <vector>
00064
00065 #include "glpk.h"
00066
00067 #include "mtk_roots.h"
00068 #include "mtk_dense_matrix.h"
00069 #include "mtk_uni_stg_grid_1d.h"
00070
00071 namespace mtk {
00072
00083 class Div1D {
00084  public:
00086   friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00087
00089   Div1D();
00090
00096   Div1D(const Div1D &div);
00097
00099   ~Div1D();
00100
00106   bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00107                       Real mimetic_threshold = kDefaultMimeticThreshold);
00108
00114   int num_bndy_coeffs() const;
00115
00121   Real *coeffs_interior() const;
00122
00128   Real *weights_crs(void) const;
00129
```

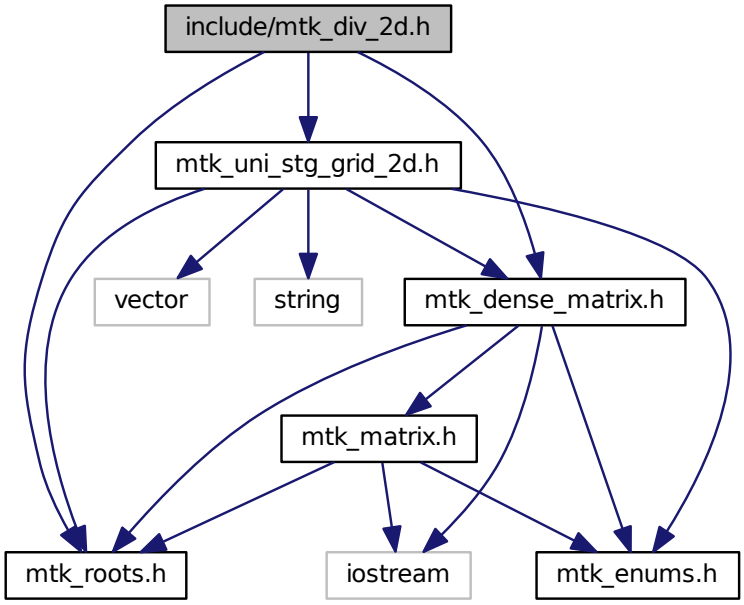
```
00135   Real *weights_cbs(void) const;
00136
00142   int num_feasible_sols() const;
00143
00149   DenseMatrix mim_bndy() const;
00150
00156   std::vector<Real> sums_rows_mim_bndy() const;
00157
00163   Real mimetic_measure() const;
00164
00170   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00171
00177   DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
      const;
00178
00179  private:
00185   bool ComputeStencilInteriorGrid(void);
00186
00193   bool ComputeRationalBasisNullSpace(void);
00194
00200   bool ComputePreliminaryApproximations(void);
00201
00207   bool ComputeWeights(void);
00208
00214   bool ComputeStencilBoundaryGrid(void);
00215
00221   bool AssembleOperator(void);
00222
00223   int order_accuracy_;
00224   int dim_null_;
00225   int num_bndy_coeffs_;
00226   int divergence_length_;
00227   int minrow_;
00228   int row_;
00229   int num_feasible_sols_;
00230
00231   DenseMatrix rat_basis_null_space_;
00232
00233   Real *coeffs_interior_;
00234   Real *prem_apps_;
00235   Real *weights_crs_;
00236   Real *weights_cbs_;
00237   Real *mim_bndy_;
00238   Real *divergence_;
00239
00240   Real mimetic_threshold_;
00241   Real mimetic_measure_;
00242
00243   std::vector<Real> sums_rows_mim_bndy_;
00244 };
00245 }
00246 #endif  // End of: MTK_INCLUDE_DIV_1D_H_
```

18.33 include/mtk_div_2d.h File Reference

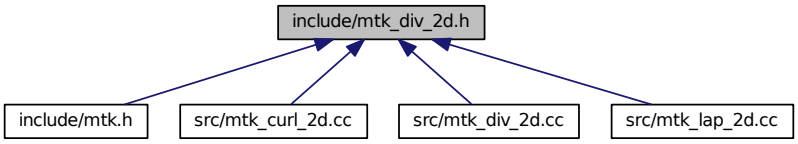
Includes the definition of the class Div2D.

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

Include dependency graph for mtk_div_2d.h:



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



Classes

- class mtk::Div2D

  Implements a 2D mimetic divergence operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.33.1 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.

18.34 mtk_div_2d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00024 2. Redistributions of source code must be done through direct
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_2D_H_
00058 #define MTK_INCLUDE_MTK_DIV_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Div2D {
00077  public:
00079   Div2D();
00080
```

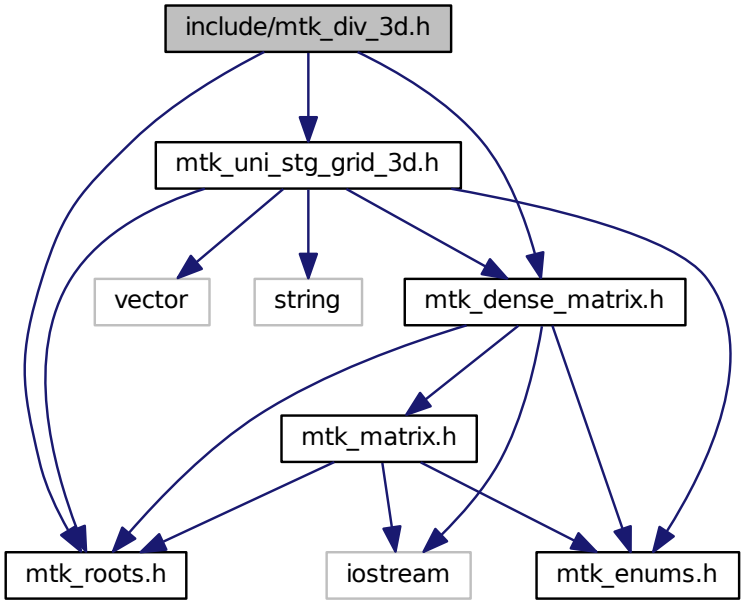
```
00086   Div2D(const Div2D &div);
00087
00089   ~Div2D();
00090
00096   bool ConstructDiv2D(const UniStgGrid2D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix divergence_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_DIV_2D_H_
```

18.35 include/mtk_div_3d.h File Reference

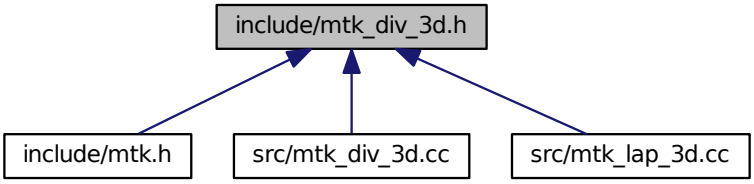
Includes the definition of the class Div3D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_div_3d.h:



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



Classes

- class mtk::Div3D

  Implements a 3D mimetic divergence operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.35.1 Detailed Description

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

Author

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

Definition in file mtk_div_3d.h.

18.36 mtk_div_3d.h

```
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00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
```

```
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
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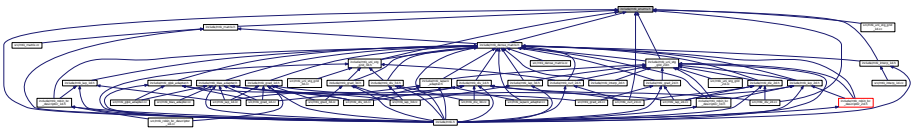
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_3D_H_
00058 #define MTK_INCLUDE_MTK_DIV_3D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_3d.h"
00063
00064 namespace mtk{
00065
00076 class Div3D {
00077  public:
00079   Div3D();
00080
00086   Div3D(const Div3D &div);
00087
00089   ~Div3D();
00090
00096   bool ConstructDiv3D(const UniStgGrid3D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix divergence_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_DIV_3D_H_
```

18.37 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::MatrixStorage::DENSE, mtk::MatrixStorage::BANDED, mtk::MatrixStorage::CRS }

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

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

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

  Interpolation operator.

18.37.1 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.

18.38 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
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00037 may be used to endorse or promote products derived from this software without
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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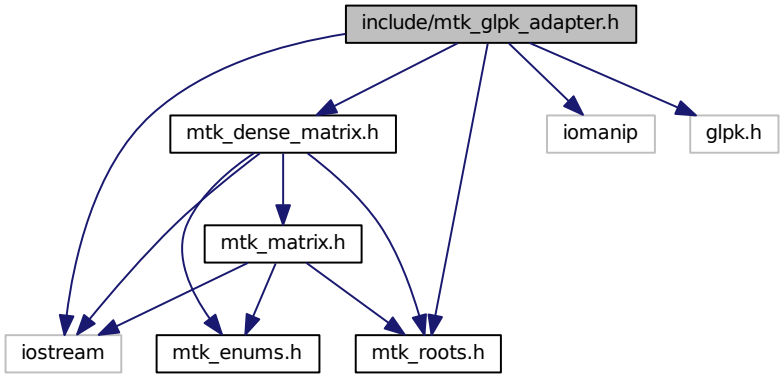
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_ENUMS_H_
00059 #define MTK_INCLUDE_ENUMS_H_
00060
00061 namespace mtk {
00062
00077 enum class MatrixStorage {
00078   DENSE,
00079   BANDED,
00080   CRS
00081 };
00082
00095 enum class MatrixOrdering {
00096   ROW_MAJOR,
00097   COL_MAJOR
00098 };
00099
00113 enum class FieldNature {
00114   SCALAR,
00115   VECTOR
00116 };
00117
00127 enum class DirInterp {
00128   SCALAR_TO_VECTOR,
00129   VECTOR_TO_SCALAR
00130 };
00131 }
00132 #endif  // End of: MTK_INCLUDE_ENUMS_H_
```

18.39 include/mtk_glpk_adapter.h File Reference

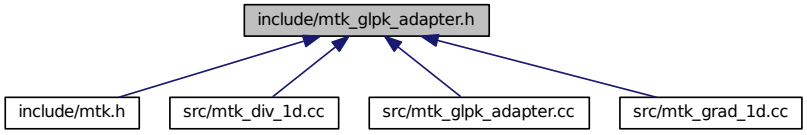
Adapter class for the GLPK API.

```
#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.

18.39.1 Detailed Description

Definition of a class that contains a collection of static member functions, 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.

18.40 mtk_glpk_adapter.h

```
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00020 /*
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00028 and a copy of the modified files should be reported once modifications are
00029 completed, unless these modifications are made through the project's GitHub
00030 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00031 should be developed and included in any deliverable.
00032
00033 2. Redistributions of source code must be done through direct
00034 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00063 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00064 */
00065
00066 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00067 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00068
00069 #include <iostream>
00070 #include <iomanip>
00071
00072 #include "glpk.h"
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_dense_matrix.h"
00076
00077 namespace mtk {
00078
00102 class GLPKAdapter {
```

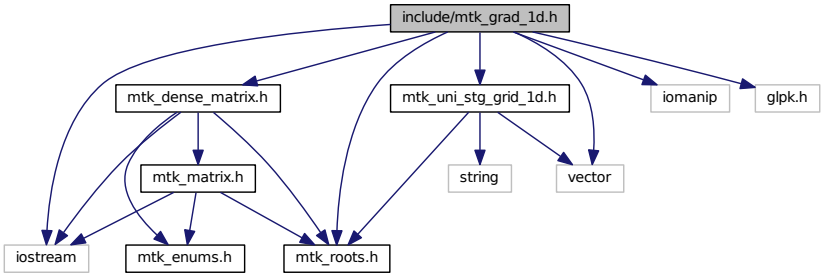
```
00103  public:
00124   static mtk::Real SolveSimplexAndCompare(
      mtk::Real *AA,
00125                                           int nrows,
00126                                           int ncols,
00127                                           int kk,
00128                                           mtk::Real *hh,
00129                                           mtk::Real *qq,
00130                                           int robjective,
00131                                           mtk::Real mimetic_threshold,
00132                                           int copy) noexcept;
00133 };
00134 }
00135 #endif  // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_
```

18.41 include/mtk_grad_1d.h File Reference

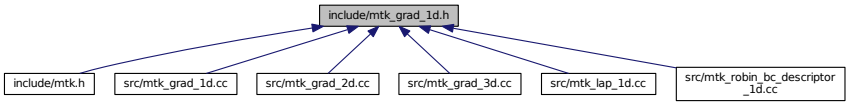
Includes the definition of the class Grad1D.

```
#include <iostream>
#include <iomanip>
#include <vector>
#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.

18.41.1 Detailed Description

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

Author

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

Definition in file mtk_grad_1d.h.

18.42 mtk_grad_1d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00024 2. Redistributions of source code must be done through direct
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
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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 <vector>
00064
00065 #include "glpk.h"
00066
00067 #include "mtk_roots.h"
00068 #include "mtk_dense_matrix.h"
00069 #include "mtk_uni_stg_grid_1d.h"
00070
00071 namespace mtk {
00072
00083 class Grad1D {
00084  public:
00086   friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00087
00089   Grad1D();
00090
00096   Grad1D(const Grad1D &grad);
00097
00099   ~Grad1D();
00100
00106   bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00107                        Real mimetic_threshold = kDefaultMimeticThreshold);
00108
00114   int num_bndy_coeffs() const;
00115
00121   Real *coeffs_interior() const;
00122
00128   Real *weights_crs(void) const;
00129
00135   Real *weights_cbs(void) const;
00136
00142   int num_feasible_sols() const;
00143
00149   DenseMatrix mim_bndy() const;
00150
00156   std::vector<Real> sums_rows_mim_bndy() const;
00157
00163   Real mimetic_measure() const;
00164
00170   DenseMatrix ReturnAsDenseMatrix(Real west,
      Real east, int num_cells_x) const;
00171
00177   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00178
00184   DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
      const;
00185
00186  private:
00192   bool ComputeStencilInteriorGrid(void);
00193
00200   bool ComputeRationalBasisNullSpace(void);
00201
00207   bool ComputePreliminaryApproximations(void);
00208
00214   bool ComputeWeights(void);
00215
00221   bool ComputeStencilBoundaryGrid(void);
00222
00228   bool AssembleOperator(void);
00229
00230   int order_accuracy_;
00231   int dim_null_;
00232   int num_bndy_approxs_;
00233   int num_bndy_coeffs_;
00234   int gradient_length_;
00235   int minrow_;
00236   int row_;
00237   int num_feasible_sols_;
00238
00239   DenseMatrix rat_basis_null_space_;
00240
00241   Real *coeffs_interior_;
00242   Real *prem_apps_;
00243   Real *weights_crs_;
00244   Real *weights_cbs_;
00245   Real *mim_bndy_;
00246   Real *gradient_;
00247
```

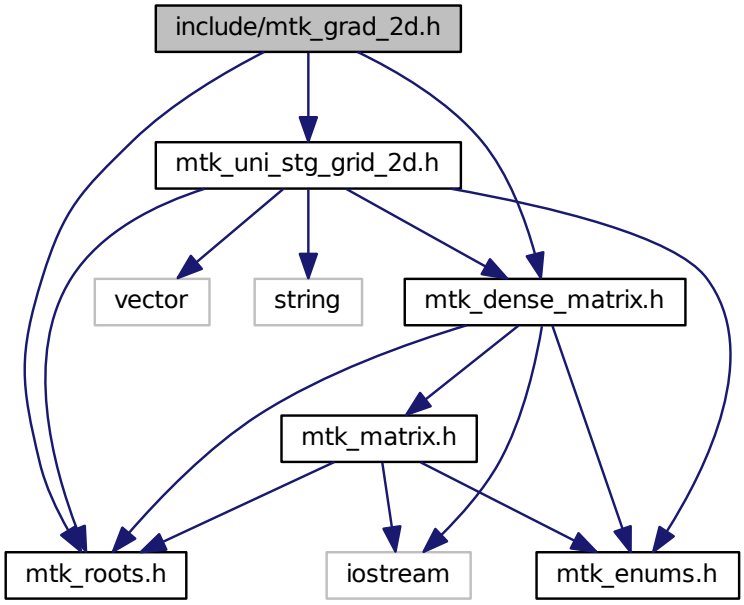
```
00248   Real mimetic_threshold_;
00249   Real mimetic_measure_;
00250
00251   std::vector<Real> sums_rows_mim_bndy_;
00252 };
00253 }
00254 #endif  // End of: MTK_INCLUDE_GRAD_1D_H_
```

18.43 include/mtk_grad_2d.h File Reference

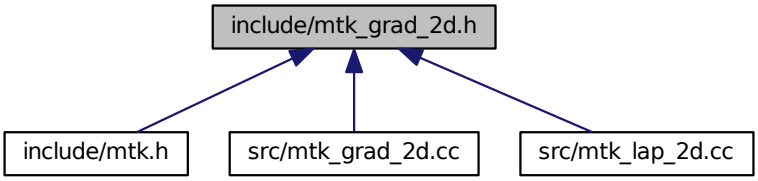
Includes the definition of the class Grad2D.

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

Include dependency graph for mtk_grad_2d.h:



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



Classes

- class mtk::Grad2D

  Implements a 2D mimetic gradient operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.43.1 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.

18.44 mtk_grad_2d.h

```
00001
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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00026
```

```
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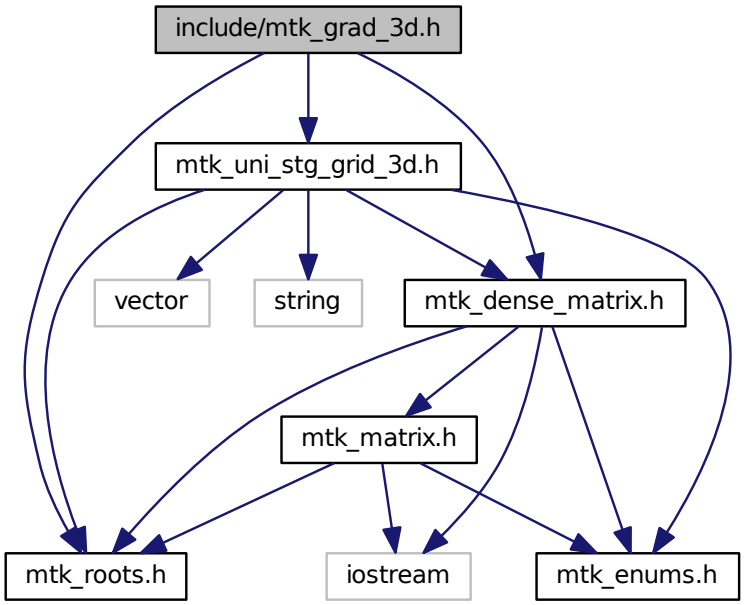
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_2D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Grad2D {
00077  public:
00079   Grad2D();
00080
00086   Grad2D(const Grad2D &grad);
00087
00089   ~Grad2D();
00090
00096   bool ConstructGrad2D(const UniStgGrid2D &grid,
00097                        int order_accuracy = kDefaultOrderAccuracy,
00098                        Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix gradient_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_GRAD_2D_H_
```

18.45 include/mtk_grad_3d.h File Reference

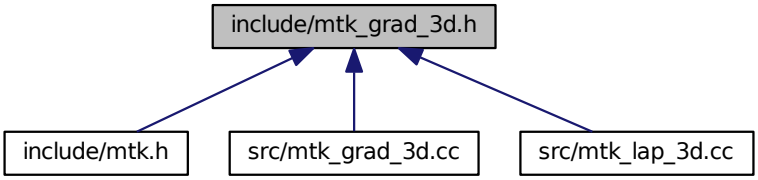
Includes the definition of the class Grad3D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_grad_3d.h:



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



Classes

- class mtk::Grad3D

  Implements a 3D mimetic gradient operator.

Namespaces

- mtk

Mimetic Methods Toolkit namespace.

18.45.1 Detailed Description

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

Author

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

Definition in file mtk_grad_3d.h.

18.46 mtk_grad_3d.h

```
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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_3D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_3D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_3d.h"
00063
00064 namespace mtk{
```

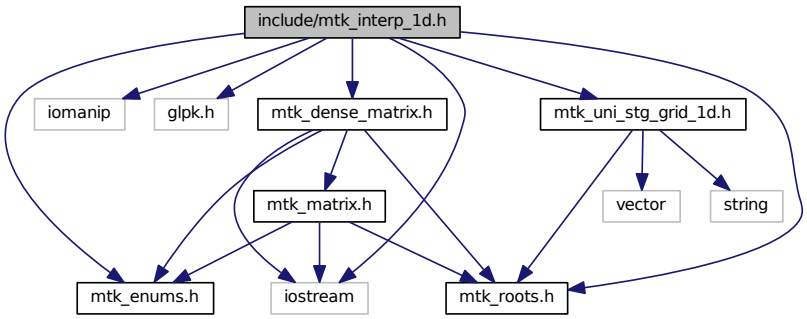
```
00065
00076 class Grad3D {
00077  public:
00079   Grad3D();
00080
00086   Grad3D(const Grad3D &grad);
00087
00089   ~Grad3D();
00090
00096   bool ConstructGrad3D(const UniStgGrid3D &grid,
00097                        int order_accuracy = kDefaultOrderAccuracy,
00098                        Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00107  private:
00108   DenseMatrix gradient_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_GRAD_3D_H_
```

18.47 include/mtk_interp_1d.h File Reference

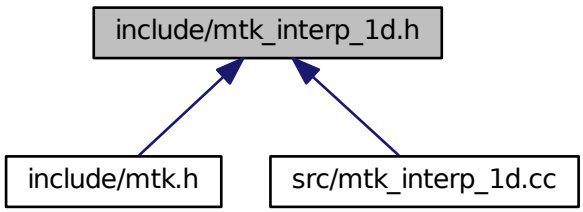
Includes the definition of the class Interp1D.

```
#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.

18.47.1 Detailed Description

Definition of a class that 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.

18.48 mtk_interp_1d.h

```
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00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00024
```

```
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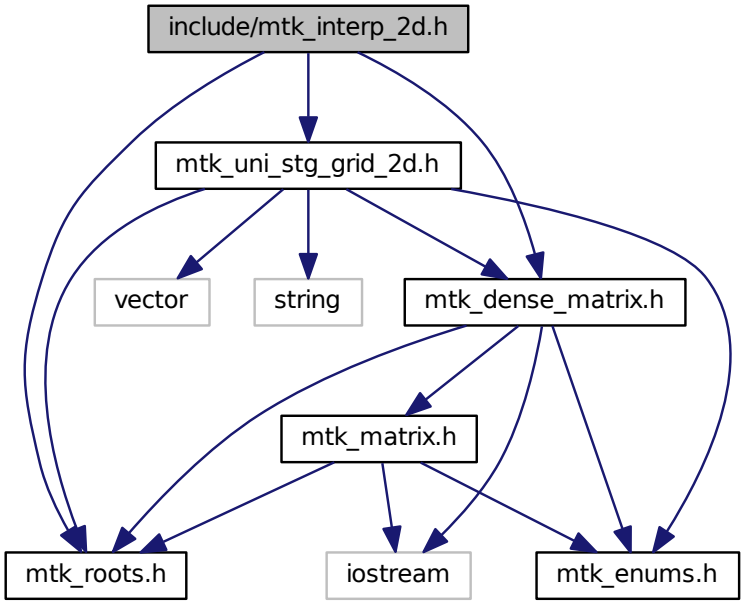
00056 */
00057
00058 #ifndef MTK_INCLUDE_INTERP_1D_H_
00059 #define MTK_INCLUDE_INTERP_1D_H_
00060
00061 #include <iostream>
00062 #include <iomanip>
00063
00064 #include "glpk.h"
00065
00066 #include "mtk_roots.h"
00067 #include "mtk_enums.h"
00068 #include "mtk_dense_matrix.h"
00069 #include "mtk_uni_stg_grid_1d.h"
00070
00071 namespace mtk {
00072
00082 class Interp1D {
00083  public:
00085   friend std::ostream& operator <<(std::ostream& stream, Interp1D &in);
00086
00088   Interp1D();
00089
00095   Interp1D(const Interp1D &interp);
00096
00098   ~Interp1D();
00099
00105   bool ConstructInterp1D(int order_accuracy =
      kDefaultOrderAccuracy,
00106                          mtk::DirInterp dir =
      mtk::DirInterp::SCALAR_TO_VECTOR);
00107
00113   Real *coeffs_interior() const;
00114
00120   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00121
00122  private:
00123   DirInterp dir_interp_;
00124
00125   int order_accuracy_;
00126
00127   Real *coeffs_interior_;
00128 };
00129 }
00130 #endif  // End of: MTK_INCLUDE_INTERP_1D_H_
```

18.49 include/mtk_interp_2d.h File Reference

Includes the definition of the class Interp2D.

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

Include dependency graph for mtk_interp_2d.h:



Classes

- class mtk::Interp2D

  Implements a 2D interpolation operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.49.1 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.

18.50 mtk_interp_2d.h

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

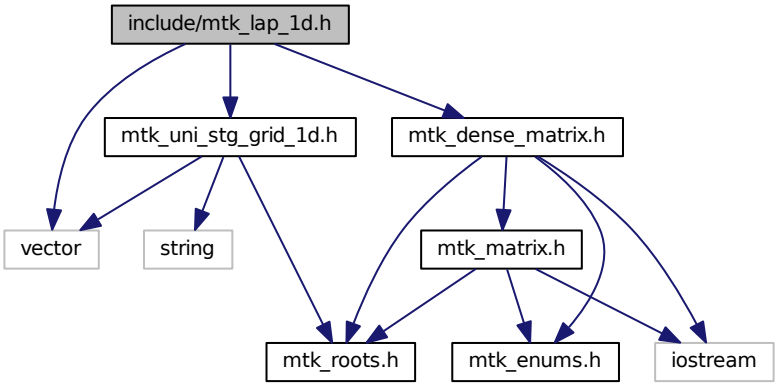
```
00098                             Real mimetic_threshold =
      kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix();
00106
00107  private:
00108   DenseMatrix interpolator_;
00109
00110   int order_accuracy_;
00111
00112   Real mimetic_threshold_;
00113 };
00114 }
00115 #endif  // End of: MTK_INCLUDE_MTK_INTERP_2D_H_
```

18.51 include/mtk_lap_1d.h File Reference

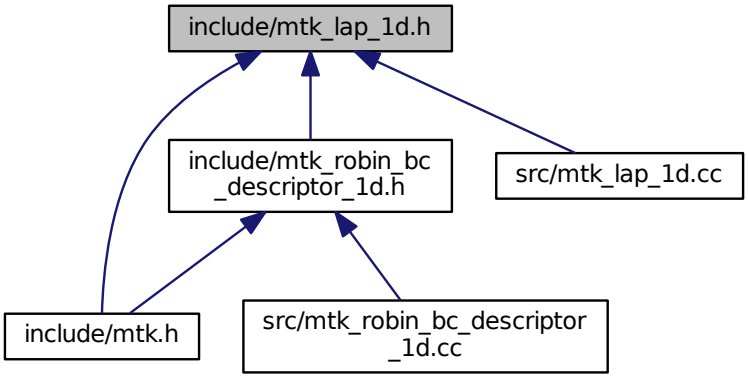
Includes the definition of the class Lap1D.

```
#include <vector>
#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.

18.51.1 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.

18.52 mtk_lap_1d.h

```
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00019 and a copy of the modified files should be reported once modifications are
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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00055 */
00056
00057 #ifndef MTK_INCLUDE_LAP_1D_H_
00058 #define MTK_INCLUDE_LAP_1D_H_
00059
00060 #include <vector>
00061
00062 #include "mtk_dense_matrix.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00078 class Lap1D {
00079  public:
00081   friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00082
00084   Lap1D();
00085
00091   Lap1D(const Lap1D &lap);
00092
00094   ~Lap1D();
00095
00101   int order_accuracy() const;
00102
00108   Real mimetic_threshold() const;
00109
00115   Real delta() const;
00116
00122   bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00123                       Real mimetic_threshold = kDefaultMimeticThreshold);
00124
00130   std::vector<Real> sums_rows_mim_bndy() const;
00131
00137   Real mimetic_measure() const;
00138
00144   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) const;
00145
00151   const mtk::Real* data(const UniStgGrid1D &grid) const;
00152
00153  private:
00154   int order_accuracy_;
00155   int laplacian_length_;
```

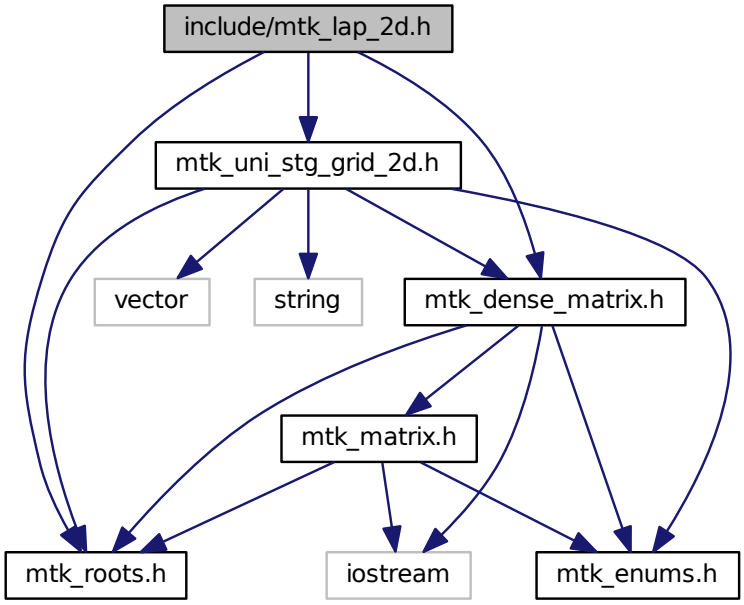
```
00156
00157   Real *laplacian_;
00158
00159   mutable Real delta_;
00160
00161   Real mimetic_threshold_;
00162   Real mimetic_measure_;
00163
00164   std::vector<Real> sums_rows_mim_bndy_;
00165 };
00166 }
00167 #endif  // End of: MTK_INCLUDE_LAP_1D_H_
```

18.53 include/mtk_lap_2d.h File Reference

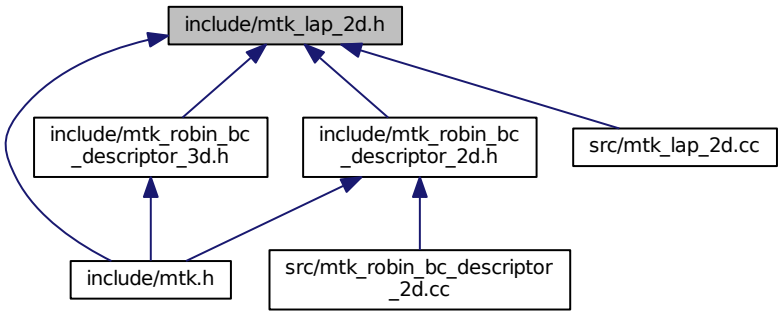
Includes the implementation of the class Lap2D.

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

Include dependency graph for mtk_lap_2d.h:



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



Classes

- class mtk::Lap2D

  Implements a 2D mimetic Laplacian operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.53.1 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.

18.54 mtk_lap_2d.h

```
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00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
```

```
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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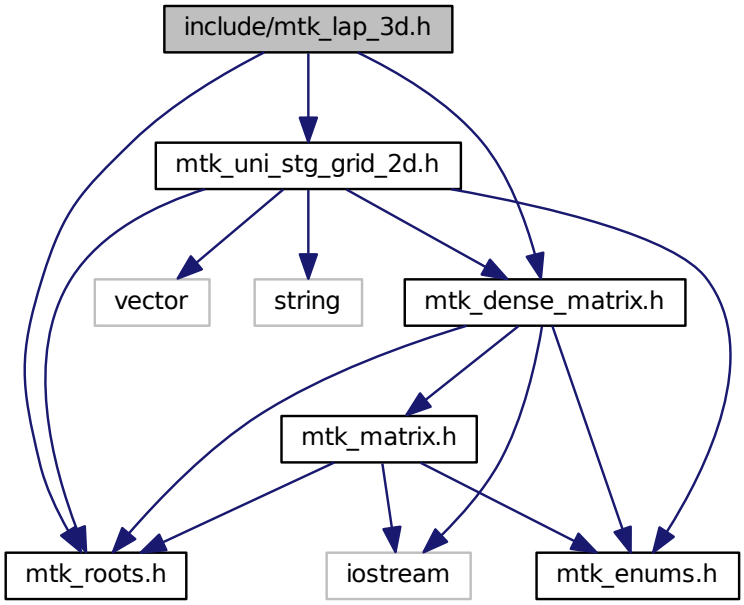
00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_LAP_2D_H_
00058 #define MTK_INCLUDE_MTK_LAP_2D_H_
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
00076 class Lap2D {
00077  public:
00079   Lap2D();
00080
00086   Lap2D(const Lap2D &lap);
00087
00089   ~Lap2D();
00090
00096   bool ConstructLap2D(const UniStgGrid2D &grid,
00097                       int order_accuracy = kDefaultOrderAccuracy,
00098                       Real mimetic_threshold = kDefaultMimeticThreshold);
00099
00105   DenseMatrix ReturnAsDenseMatrix() const;
00106
00112   Real *data() const;
00113
00114  private:
00115   DenseMatrix laplacian_;
00116
00117   int order_accuracy_;
00118
00119   Real mimetic_threshold_;
00120 };
00121 }
00122 #endif  // End of: MTK_INCLUDE_MTK_LAP_2D_H_
```

18.55 include/mtk_lap_3d.h File Reference

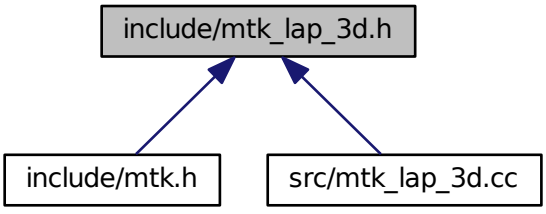
Includes the implementation of the class Lap3D.

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

Include dependency graph for mtk_lap_3d.h:



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



Classes

- class mtk::Lap3D

  Implements a 3D mimetic Laplacian operator.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.55.1 Detailed Description

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

Author

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

Definition in file mtk_lap_3d.h.

18.56 mtk_lap_3d.h

```
00001
00011 /*
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00013 University. All rights reserved.
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_LAP_3D_H_
00058 #define MTK_INCLUDE_MTK_LAP_3D_H_
00059
00060 #include "mtk_roots.h"
```

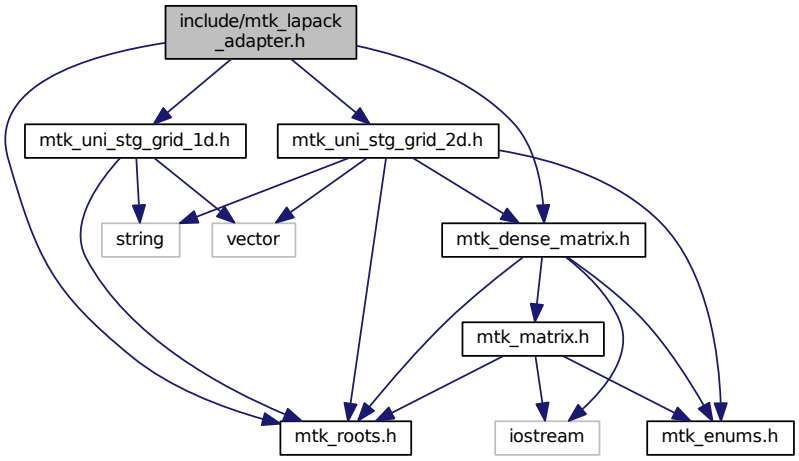
```
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00076 class Lap3D {
00077  public:
00079   UniStgGrid3D operator*(const UniStgGrid3D &grid) const;
00080
00082   Lap3D();
00083
00089   Lap3D(const Lap3D &lap);
00090
00092   ~Lap3D();
00093
00099   bool ConstructLap3D(const UniStgGrid3D &grid,
00100                       int order_accuracy = kDefaultOrderAccuracy,
00101                       Real mimetic_threshold = kDefaultMimeticThreshold);
00102
00108   DenseMatrix ReturnAsDenseMatrix() const;
00109
00115   Real *data() const;
00116
00117  private:
00118   DenseMatrix laplacian_;
00119
00120   int order_accuracy_;
00121
00122   Real mimetic_threshold_;
00123 };
00124 }
00125 #endif  // End of: MTK_INCLUDE_MTK_LAP_3D_H_
```

18.57 include/mtk_lapack_adapter.h File Reference

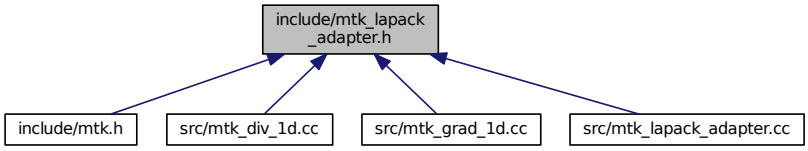
Adapter class for the LAPACK API.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_uni_stg_grid_2d.h"
```

Include dependency graph for mtk_lapack_adapter.h:



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



Classes

- class mtk::LAPACKAdapter

  Adapter class for the LAPACK API.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.57.1 Detailed Description

Definition of a class that contains a collection of static member functions, 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.

18.58 mtk_lapack_adapter.h

```
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00022 University. All rights reserved.
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00025 are permitted provided that the following conditions are met:
00026
```

```
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00028 and a copy of the modified files should be reported once modifications are
00029 completed, unless these modifications are made through the project's GitHub
00030 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00031 should be developed and included in any deliverable.
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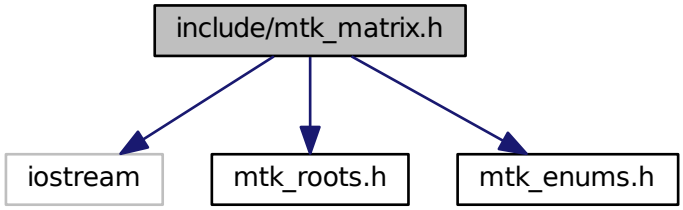
00061 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00062 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00063 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00064 */
00065
00066 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00067 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00068
00069 #include "mtk_roots.h"
00070 #include "mtk_dense_matrix.h"
00071 #include "mtk_uni_stg_grid_1d.h"
00072 #include "mtk_uni_stg_grid_2d.h"
00073
00074 namespace mtk {
00075
00094 class LAPACKAdapter {
00095  public:
00106   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00107                               mtk::Real *rhs);
00108
00119   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00120                               mtk::DenseMatrix &rr);
00121
00132   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00133                               mtk::UniStgGrid1D &rhs);
00134
00135
00146   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00147                               mtk::UniStgGrid2D &rhs);
00148
00160   static int SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00161                                          mtk::Real *ob_,
00162                                          int ob_ld_);
00163
00175   static mtk::DenseMatrix QRFactorDenseMatrix(
      DenseMatrix &matrix);
00176 };
00177 }
00178 #endif  // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_
```

18.59 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.

18.59.1 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.

18.60 mtk_matrix.h

```
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00010 /*
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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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() noexcept ;
00089
00095   MatrixStorage storage() const noexcept;
00096
00102   MatrixOrdering ordering() const noexcept;
00103
00109   int num_rows() const noexcept;
00110
00116   int num_cols() const noexcept;
00117
00123   int num_values() const noexcept;
00124
00134   int ld() const noexcept;
00135
00141   int num_zero() const noexcept;
```

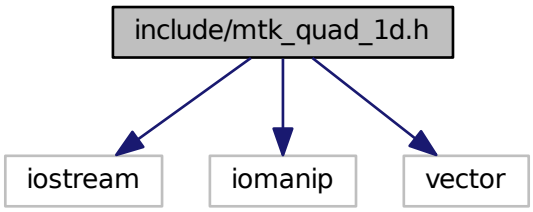
```
00142
00148   int num_non_zero() const noexcept;
00149
00157   int num_null() const noexcept;
00158
00166   int num_non_null() const noexcept;
00167
00173   int kl() const noexcept;
00174
00180   int ku() const noexcept;
00181
00187   int bandwidth() const noexcept;
00188
00196   Real abs_density() const noexcept;
00197
00205   Real rel_density() const noexcept;
00206
00214   Real abs_sparsity() const noexcept;
00215
00223   Real rel_sparsity() const noexcept;
00224
00232   void set_storage(const MatrixStorage &tt) noexcept;
00233
00241   void set_ordering(const MatrixOrdering &oo) noexcept;
00242
00248   void set_num_rows(const int &num_rows) noexcept;
00249
00255   void set_num_cols(const int &num_cols) noexcept;
00256
00262   void set_num_zero(const int &in) noexcept;
00263
00269   void set_num_null(const int &in) noexcept;
00270
00272   void IncreaseNumZero() noexcept;
00273
00275   void IncreaseNumNull() noexcept;
00276
00277  private:
00278   MatrixStorage storage_;
00279
00280   MatrixOrdering ordering_;
00281
00282   int num_rows_;
00283   int num_cols_;
00284   int num_values_;
00285   int ld_;
00286
00287   int num_zero_;
00288   int num_non_zero_;
00289   int num_null_;
00290   int num_non_null_;
00291
00292   int kl_;
00293   int ku_;
00294   int bandwidth_;
00295
00296   Real abs_density_;
00297   Real rel_density_;
00298   Real abs_sparsity_;
00299   Real rel_sparsity_;
00300 };
00301 }
00302 #endif  // End of: MTK_INCLUDE_MATRIX_H_
```

18.61 include/mtk_quad_1d.h File Reference

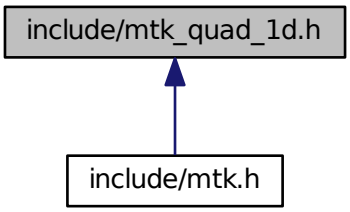
Includes the definition of the class Quad1D.

```
#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.

18.61.1 Detailed Description

Definition of a class that 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.

18.62 mtk_quad_1d.h

```
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00015 /*
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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
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00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #ifndef MTK_INCLUDE_QUAD_1D_H_
00062 #define MTK_INCLUDE_QUAD_1D_H_
00063
00064 #include <iostream>
00065 #include <iomanip>
00066
00067 #include <vector>
00068
00069 namespace mtk {
00070
00081 class Quad1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Quad1D &in);
00085
00087   Quad1D();
00088
00094   Quad1D(const Quad1D &quad);
00095
```

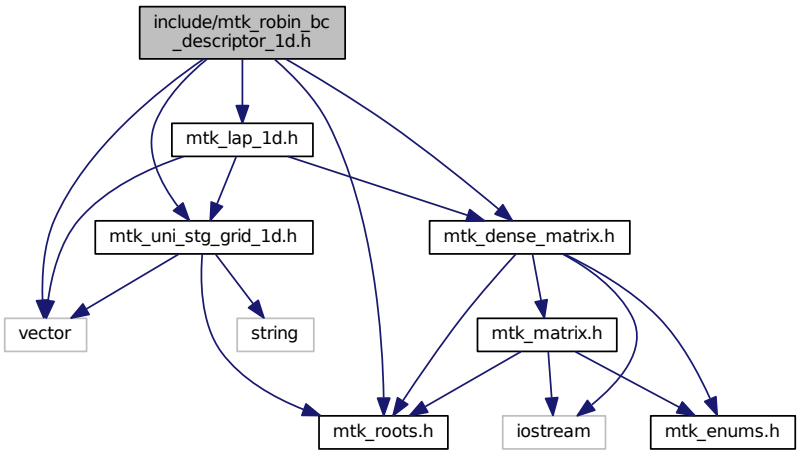
```
00097   ~Quad1D();
00098
00104   int degree_approximation() const;
00105
00111   Real *weights() const;
00112
00121   Real Integrate(Real (*Integrand)(Real xx), UniStgGrid1D grid) const;
00122
00123  private:
00124   int degree_approximation_;
00125
00126   std::vector<Real> weights_;
00127 };
00128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

18.63 include/mtk_robin_bc_descriptor_1d.h File Reference

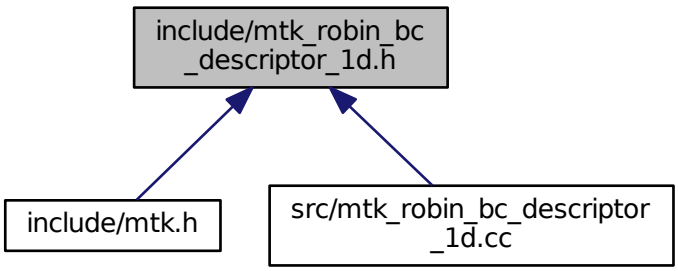
Impose Robin boundary conditions on the operators and on the grids.

```
#include <vector>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_lap_1d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_1d.h:



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



Classes

- class mtk::RobinBCDescriptor1D

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

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Typedefs

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

  A function of a BC coefficient evaluated on a 0D domain and time.

18.63.1 Detailed Description

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

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

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

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

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

$$\delta_a(a,t)u(a,t) - \eta_a(a,t)u'(a,t) = \beta_a(a,t),$$

$$\delta_b(b,t)u(b,t)+\eta_b(b,t)u'(b,t)=\beta_b(b,t).$$

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the condition in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Author

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

Definition in file mtk_robin_bc_descriptor_1d.h.

18.64 mtk_robin_bc_descriptor_1d.h

```
00001
00043 /*
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00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
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00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #include <vector>
00090
00091 #include "mtk_roots.h"
00092 #include "mtk_dense_matrix.h"
00093 #include "mtk_uni_stg_grid_1d.h"
```

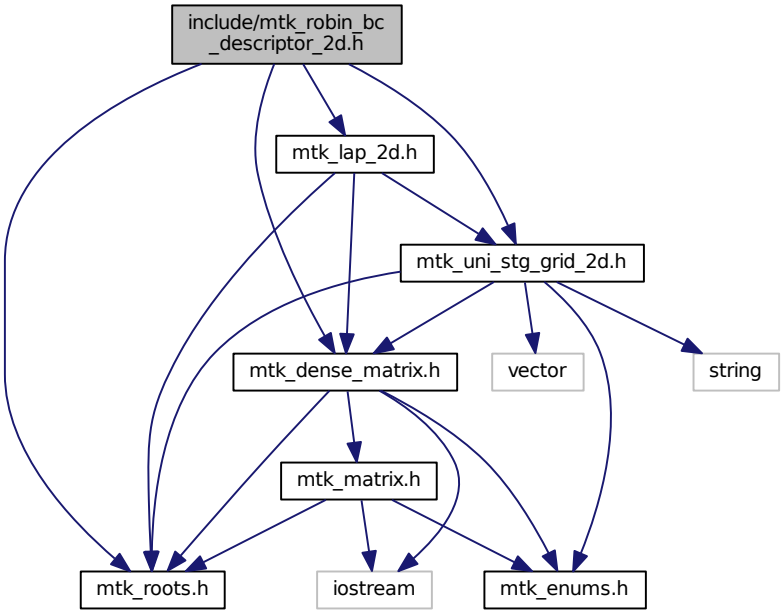
```
00094 #include "mtk_lap_1d.h"
00095
00096 #ifndef MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
00097 #define MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
00098
00099 namespace mtk {
00111 typedef Real (*CoefficientFunction0D)(const Real &tt);
00112
00155 class RobinBCDescriptor1D {
00156  public:
00158   RobinBCDescriptor1D();
00159
00165   RobinBCDescriptor1D(const RobinBCDescriptor1D &desc);
00166
00168   ~RobinBCDescriptor1D() noexcept;
00169
00175   int highest_order_diff_west() const noexcept;
00176
00182   int highest_order_diff_east() const noexcept;
00183
00189   void PushBackWestCoeff(CoefficientFunction0D cw);
00190
00196   void PushBackEastCoeff(CoefficientFunction0D ce);
00197
00203   void set_west_condition(Real (*west_condition)(const
      Real &tt)) noexcept;
00204
00210   void set_east_condition(Real (*east_condition)(const
      Real &tt)) noexcept;
00211
00221   bool ImposeOnLaplacianMatrix(const Lap1D &lap,
00222                                DenseMatrix &matrix,
00223                                const Real &time = mtk::kZero) const;
00230   void ImposeOnGrid(UniStgGrid1D &grid, const Real &time =
      mtk::kZero) const;
00231
00232  private:
00233   int highest_order_diff_west_;
00234   int highest_order_diff_east_;
00235
00236   std::vector<CoefficientFunction0D> west_coefficients_;
00237   std::vector<CoefficientFunction0D> east_coefficients_;
00238
00239   Real (*west_condition_)(const Real &tt);
00240   Real (*east_condition_)(const Real &tt);
00241 };
00242 }
00243 #endif  // End of: MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_1D_H_
```

18.65 include/mtk_robin_bc_descriptor_2d.h File Reference

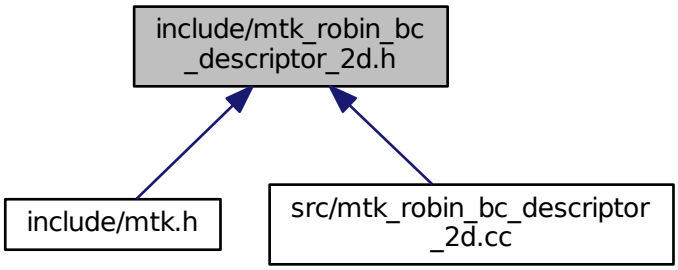
Impose Robin boundary conditions on the operators and on the grids.

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

Include dependency graph for mtk_robin_bc_descriptor_2d.h:



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



Classes

- class mtk::RobinBCDescriptor2D

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

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Typedefs

- typedef Real(∗ mtk::CoefficientFunction1D)(const Real &xx, const Real &tt)

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

18.65.1 Detailed Description

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

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Author

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

Definition in file mtk_robin_bc_descriptor_2d.h.

18.66 mtk_robin_bc_descriptor_2d.h

```
00001
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00039 are permitted provided that the following conditions are met:
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00042 and a copy of the modified files should be reported once modifications are
00043 completed, unless these modifications are made through the project's GitHub
00044 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00045 should be developed and included in any deliverable.
00046
00047 2. Redistributions of source code must be done through direct
00048 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00049
```

```
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00078 */
00079
00080 #ifndef MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_2D_H_
00081 #define MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_2D_H_
00082
00083 #include "mtk_roots.h"
00084 #include "mtk_dense_matrix.h"
00085 #include "mtk_lap_2d.h"
00086 #include "mtk_uni_stg_grid_2d.h"
00087
00088 namespace mtk{
00089
00097 typedef Real (*CoefficientFunction1D)(const Real &xx, const
      Real &tt);
00098
00132 class RobinBCDescriptor2D {
00133  public:
00135   RobinBCDescriptor2D();
00136
00142   RobinBCDescriptor2D(const RobinBCDescriptor2D &desc);
00143
00145   ~RobinBCDescriptor2D() noexcept;
00146
00152   int highest_order_diff_west() const noexcept;
00153
00159   int highest_order_diff_east() const noexcept;
00160
00166   int highest_order_diff_south() const noexcept;
00167
00173   int highest_order_diff_north() const noexcept;
00174
00181   void PushBackWestCoeff(CoefficientFunction1D cw);
00182
00189   void PushBackEastCoeff(CoefficientFunction1D ce);
00190
00197   void PushBackSouthCoeff(CoefficientFunction1D cs);
00198
00205   void PushBackNorthCoeff(CoefficientFunction1D cn);
00206
00213   void set_west_condition(Real (*west_condition)(const
      Real &yy,
00214                                                  const Real &tt)) noexcept;
00215
00222   void set_east_condition(Real (*east_condition)(const
      Real &yy,
00223                                                  const Real &tt)) noexcept;
00224
00231   void set_south_condition(Real (*south_condition)(const
      Real &xx,
00232                                                    const Real &tt)) noexcept;
00233
00240   void set_north_condition(Real (*north_condition)(const
      Real &xx,
```

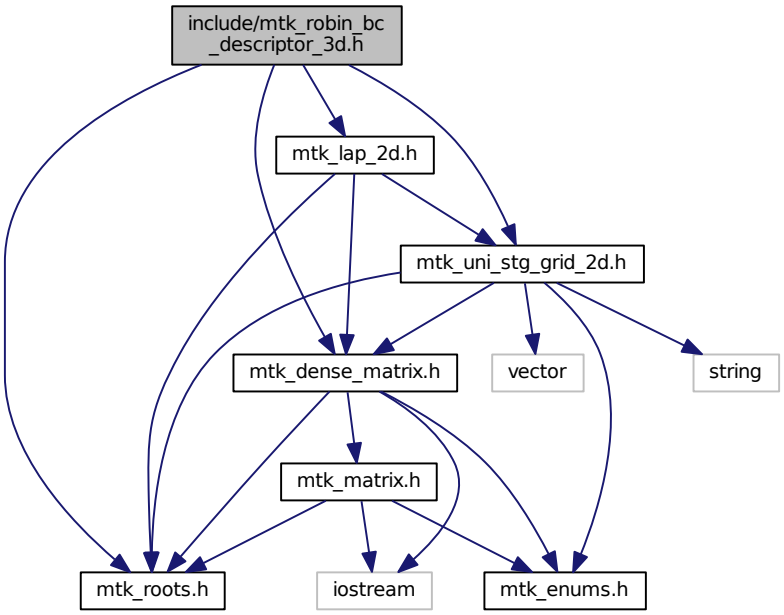
```
00241                                                 const Real &tt)) noexcept;
00242
00251   bool ImposeOnLaplacianMatrix(const Lap2D &lap,
00252                               const UniStgGrid2D &grid,
00253                               DenseMatrix &matrix,
00254                               const Real &time = kZero) const;
00261   void ImposeOnGrid(UniStgGrid2D &grid, const Real &time =
      kZero) const;
00262
00263 private:
00272   bool ImposeOnSouthBoundaryNoSpace(const Lap2D &lap,
00273                                     const UniStgGrid2D &grid,
00274                                     DenseMatrix &matrix,
00275                                     const Real &time = kZero) const;
00284   bool ImposeOnNorthBoundaryNoSpace(const Lap2D &lap,
00285                                     const UniStgGrid2D &grid,
00286                                     DenseMatrix &matrix,
00287                                     const Real &time = kZero) const;
00296   bool ImposeOnWestBoundaryNoSpace(const Lap2D &lap,
00297                                    const UniStgGrid2D &grid,
00298                                    DenseMatrix &matrix,
00299                                    const Real &time = kZero) const;
00308   bool ImposeOnEastBoundaryNoSpace(const Lap2D &lap,
00309                                    const UniStgGrid2D &grid,
00310                                    DenseMatrix &matrix,
00311                                    const Real &time = kZero) const;
00320   bool ImposeOnSouthBoundaryWithSpace(const Lap2D &lap,
00321                                       const UniStgGrid2D &grid,
00322                                       DenseMatrix &matrix,
00323                                       const Real &time = kZero) const;
00332   bool ImposeOnNorthBoundaryWithSpace(const Lap2D &lap,
00333                                       const UniStgGrid2D &grid,
00334                                       DenseMatrix &matrix,
00335                                       const Real &time = kZero) const;
00344   bool ImposeOnWestBoundaryWithSpace(const Lap2D &lap,
00345                                      const UniStgGrid2D &grid,
00346                                      DenseMatrix &matrix,
00347                                      const Real &time = kZero) const;
00356   bool ImposeOnEastBoundaryWithSpace(const Lap2D &lap,
00357                                      const UniStgGrid2D &grid,
00358                                      DenseMatrix &matrix,
00359                                      const Real &time = kZero) const;
00360
00361   int highest_order_diff_west_;
00362   int highest_order_diff_east_;
00363   int highest_order_diff_south_;
00364   int highest_order_diff_north_;
00365
00366   std::vector<CoefficientFunction1D> west_coefficients_;
00367   std::vector<CoefficientFunction1D> east_coefficients_;
00368   std::vector<CoefficientFunction1D> south_coefficients_;
00369   std::vector<CoefficientFunction1D> north_coefficients_;
00370
00371   Real (*west_condition_)(const Real &xx, const Real &tt);
00372   Real (*east_condition_)(const Real &xx, const Real &tt);
00373   Real (*south_condition_)(const Real &yy, const Real &tt);
00374   Real (*north_condition_)(const Real &yy, const Real &tt);
00375 };
00376 }
00377 #endif  // End of: MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_2D_H_
```

18.67 include/mtk_robin_bc_descriptor_3d.h File Reference

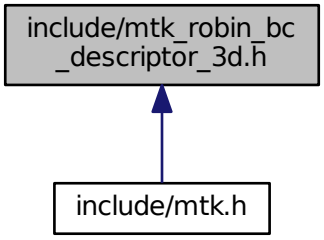
Impose Robin boundary conditions on the operators and on the grids.

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

Include dependency graph for mtk_robin_bc_descriptor_3d.h:



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



Classes

- class mtk::RobinBCDescriptor3D

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

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Typedefs

- typedef Real(∗ mtk::CoefficientFunction2D)(const Real &xx, const Real &yy, const Real &tt)

  A function of a BC coefficient evaluated on a 2D domain and time.

18.67.1 Detailed Description

This class presents an interface for the user to specify Robin boundary conditions on 3D mimetic operators and the grids they are acting on.

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary. These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Author

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

Definition in file mtk_robin_bc_descriptor_3d.h.

18.68 mtk_robin_bc_descriptor_3d.h

```
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00042 and a copy of the modified files should be reported once modifications are
00043 completed, unless these modifications are made through the project's GitHub
00044 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00045 should be developed and included in any deliverable.
00046
00047 2. Redistributions of source code must be done through direct
00048 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

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00075 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00076 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00077 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00078 */
00079
00080 #ifndef MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_3D_H_
00081 #define MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_3D_H_
00082
00083 #include "mtk_roots.h"
00084 #include "mtk_dense_matrix.h"
00085 #include "mtk_lap_2d.h"
00086 #include "mtk_uni_stg_grid_2d.h"
00087
00088 namespace mtk{
00089
00097 typedef Real (*CoefficientFunction2D)(const Real &xx,
00098                                       const Real &yy,
00099                                       const Real &tt);
00100
00134 class RobinBCDescriptor3D {
00135  public:
00137   RobinBCDescriptor3D();
00138
00144   RobinBCDescriptor3D(const RobinBCDescriptor3D &desc);
00145
00147   ~RobinBCDescriptor3D() noexcept;
00148
00154   int highest_order_diff_west() const noexcept;
00155
00156   // ...
00157
00164   void PushBackWestCoeff(CoefficientFunction2D cw);
00165
00166   // ...
00167
00174   void set_west_condition(Real (*west_condition)(const
      Real &xx,
00175                                                 const Real &yy,
00176                                                 const Real &tt)) noexcept;
00177
00178   // ...
00179
00188   bool ImposeOnLaplacianMatrix(const Lap3D &lap,
00189                                const UniStgGrid3D &grid,
00190                                DenseMatrix &matrix,
00191                                const Real &time = kZero) const;
00198   void ImposeOnGrid(UniStgGrid3D &grid, const Real &time =
      kZero) const;
00199
00200 private:
00209   bool ImposeOnSouthBoundaryNoSpace(const Lap2D &lap,
00210                                     const UniStgGrid2D &grid,
00211                                     DenseMatrix &matrix,
00212                                     const Real &time = kZero) const;
00221   bool ImposeOnNorthBoundaryNoSpace(const Lap2D &lap,
00222                                     const UniStgGrid2D &grid,
```
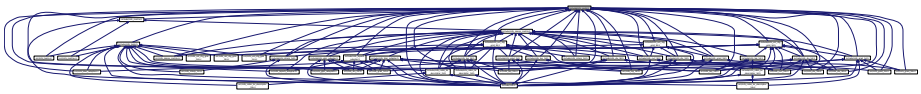

```
00223                                    DenseMatrix &matrix,
00224                                    const Real &time = kZero) const;
00233   bool ImposeOnWestBoundaryNoSpace(const Lap2D &lap,
00234                                    const UniStgGrid2D &grid,
00235                                    DenseMatrix &matrix,
00236                                    const Real &time = kZero) const;
00245   bool ImposeOnEastBoundaryNoSpace(const Lap2D &lap,
00246                                    const UniStgGrid2D &grid,
00247                                    DenseMatrix &matrix,
00248                                    const Real &time = kZero) const;
00257   bool ImposeOnSouthBoundaryWithSpace(const Lap2D &lap,
00258                                       const UniStgGrid2D &grid,
00259                                       DenseMatrix &matrix,
00260                                       const Real &time = kZero) const;
00269   bool ImposeOnNorthBoundaryWithSpace(const Lap2D &lap,
00270                                       const UniStgGrid2D &grid,
00271                                       DenseMatrix &matrix,
00272                                       const Real &time = kZero) const;
00281   bool ImposeOnWestBoundaryWithSpace(const Lap2D &lap,
00282                                      const UniStgGrid2D &grid,
00283                                      DenseMatrix &matrix,
00284                                      const Real &time = kZero) const;
00293   bool ImposeOnEastBoundaryWithSpace(const Lap2D &lap,
00294                                      const UniStgGrid2D &grid,
00295                                      DenseMatrix &matrix,
00296                                      const Real &time = kZero) const;
00297
00298   int highest_order_diff_west_;
00299   int highest_order_diff_east_;
00300   int highest_order_diff_south_;
00301   int highest_order_diff_north_;
00302   int highest_order_diff_bottom_;
00303   int highest_order_diff_top_;
00304
00305   std::vector<CoefficientFunction2D> west_coefficients_;
00306   std::vector<CoefficientFunction2D> east_coefficients_;
00307   std::vector<CoefficientFunction2D> south_coefficients_;
00308   std::vector<CoefficientFunction2D> north_coefficients_;
00309   std::vector<CoefficientFunction2D> bottom_coefficients_;
00310   std::vector<CoefficientFunction2D> top_coefficients_;
00311
00312   Real (*west_condition_)(const Real &xx,
00313                           const Real &yy,
00314                           const Real &tt);
00315   Real (*east_condition_)(const Real &xx,
00316                           const Real &yy,
00317                           const Real &tt);
00318   Real (*south_condition_)(const Real &xx,
00319                            const Real &yy,
00320                            const Real &tt);
00321   Real (*north_condition_)(const Real &xx,
00322                            const Real &yy,
00323                            const Real &tt);
00324   Real (*bottom_condition_)(const Real &xx,
00325                             const Real &yy,
00326                             const Real &tt);
00327   Real (*top_condition_)(const Real &xx,
00328                          const Real &yy,
00329                          const Real &tt);
00330 };
00331 }
00332 #endif  // End of: MTK_INCLUDE_ROBIN_BC_DESCRIPTOR_3D_H_
```

18.69 include/mtk_roots.h File Reference

Fundamental definitions to be used across all classes of the MTK.

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



Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Typedefs

- typedef float mtk::Real

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

Variables

- const float mtk::kZero {0.0f}

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

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

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

  Considered tolerance for comparisons in numerical methods.
- const float mtk::kDefaultMimeticThreshold {1e-6f}

  Default tolerance for higher-order mimetic operators.
- const int mtk::kDefaultOrderAccuracy {2}

  Default order of accuracy for mimetic operators.
- const int mtk::kCriticalOrderAccuracyGrad {10}

  At this order (and higher) we must use the CBSA to construct gradients.
- const int mtk::kCriticalOrderAccuracyDiv {8}

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

18.69.1 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 Test selective precision mechanisms.

Definition in file mtk_roots.h.

18.70 mtk_roots.h

```
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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:
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00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
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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_ROOTS_H_
00062 #define MTK_INCLUDE_ROOTS_H_
00063
00069 namespace mtk {
00070
00090 #ifdef MTK_PRECISION_DOUBLE
00091 typedef double Real;
00092 #else
00093 typedef float Real;
00094 #endif
00095
00121 #ifdef MTK_PRECISION_DOUBLE
00122 const double kZero{0.0};
00123 const double kOne{1.0};
00124 const double kTwo{2.0};
00125 #else
00126 const float kZero{0.0f};
00127 const float kOne{1.0f};
00128 const float kTwo{2.0f};
00129 #endif
00130
00140 #ifdef MTK_PRECISION_DOUBLE
00141 const double kDefaultTolerance{1e-7};
00142 #else
00143 const float kDefaultTolerance{1e-7f};
00144 #endif
00145
00155 #ifdef MTK_PRECISION_DOUBLE
00156 const double kDefaultMimeticThreshold{1e-6};
00157 #else
00158 const float kDefaultMimeticThreshold{1e-6f};
```

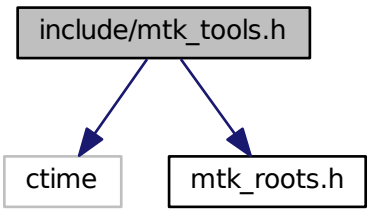
```
00159 #endif
00160
00168 const int kDefaultOrderAccuracy{2};
00169
00177 const int kCriticalOrderAccuracyGrad{10};
00178
00186 const int kCriticalOrderAccuracyDiv{8};
00187 }
00188 #endif  // End of: MTK_INCLUDE_ROOTS_H_
```

18.71 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.

18.71.1 Detailed Description

Definition of a class providing basic tools to ensure execution correctness, and to assists with unitary testing.

Author

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

Note

Performance Tip 8.1. If they do not need to be modified by the called function, pass large objects using pointers to constant data or references to constant data, to obtain the performance benefits of pass-by-reference.

Definition in file mtk_tools.h.

18.72 mtk_tools.h

```
00001
00015 /*
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00017 University. All rights reserved.
00018
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00020 are permitted provided that the following conditions are met:
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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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
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00035 4. Usage of the binary form on proprietary applications shall require explicit
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #ifndef MTK_INCLUDE_TOOLS_H_
00062 #define MTK_INCLUDE_TOOLS_H_
00063
00064 #include <ctime>
00065
00066 #include "mtk_roots.h"
00067
00068 namespace mtk {
00069
00080 class Tools {
00081  public:
00092   static void Prevent(const bool complement,
00093                       const char *const fname,
```

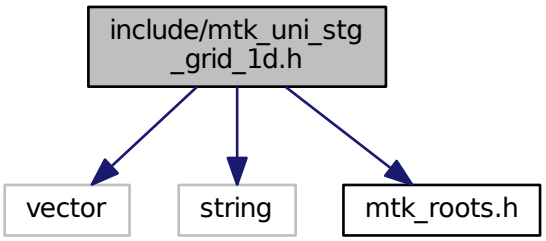
```
00094                       int lineno,
00095                       const char *const fxname) noexcept;
00096
00102   static void BeginUnitTestNo(const int &nn) noexcept;
00103
00109   static void EndUnitTestNo(const int &nn) noexcept;
00110
00116   static void Assert(const bool &condition) noexcept;
00117
00118  private:
00119   static int test_number_;
00120
00121   static Real duration_;
00122
00123   static clock_t begin_time_;
00124 };
00125 }
00126 #endif  // End of: MTK_INCLUDE_TOOLS_H_
```

18.73 include/mtk_uni_stg_grid_1d.h File Reference

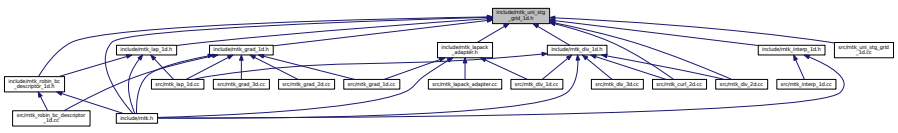
Definition of an 1D uniform staggered grid.

```
#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.

18.73.1 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.

18.74 mtk_uni_stg_grid_1d.h

```
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00012 /*
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_1D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_1D_H_
```

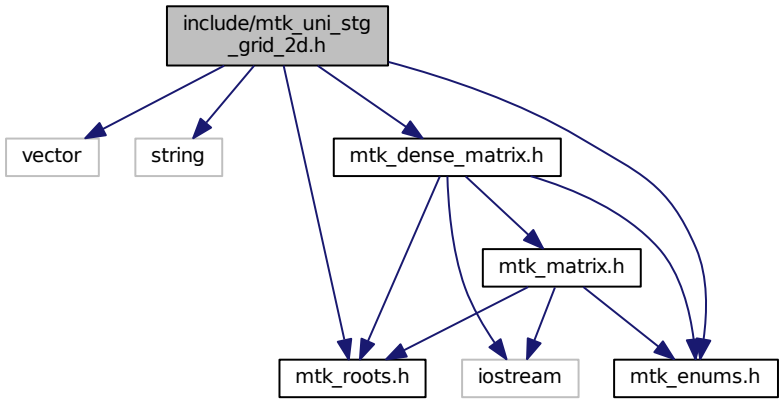
```
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065
00066 namespace mtk {
00067
00077 class UniStgGrid1D {
00078  public:
00080   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid1D &in);
00081
00083   UniStgGrid1D();
00084
00090   UniStgGrid1D(const UniStgGrid1D &grid);
00091
00102   UniStgGrid1D(const Real &west_bndy_x,
00103                const Real &east_bndy_x,
00104                const int &num_cells_x,
00105                const mtk::FieldNature &nature =
      mtk::FieldNature::SCALAR);
00106
00108   ~UniStgGrid1D();
00109
00115   Real west_bndy_x() const;
00116
00122   Real east_bndy_x() const;
00123
00129   Real delta_x() const;
00130
00138   const Real *discrete_domain_x() const;
00139
00147   Real *discrete_field();
00148
00154   int num_cells_x() const;
00155
00159   void GenerateDiscreteDomainX();
00160
00166   void BindScalarField(Real (*ScalarField)(const Real &xx));
00167
00178   void BindVectorField(Real (*VectorField)(Real xx));
00179
00191   bool WriteToFile(std::string filename,
00192                    std::string space_name,
00193                    std::string field_name) const;
00194
00195  private:
00196   FieldNature nature_;
00197
00198   std::vector<Real> discrete_domain_x_;
00199   std::vector<Real> discrete_field_;
00200
00201   Real west_bndy_x_;
00202   Real east_bndy_x_;
00203   Real num_cells_x_;
00204   Real delta_x_;
00205 };
00206 }
00207 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_
```

18.75 include/mtk_uni_stg_grid_2d.h File Reference

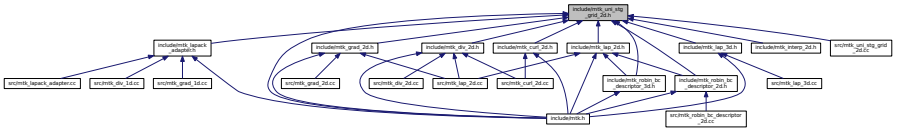
Definition of an 2D uniform staggered grid.

```
#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.

18.75.1 Detailed Description

Definition of an 2D uniform staggered grid.

Author

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

Todo Create overloaded binding routines that read data from files.

Definition in file mtk_uni_stg_grid_2d.h.

18.76 mtk_uni_stg_grid_2d.h

```
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00012 /*
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_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::FieldNature::SCALAR);
00114
00116   ~UniStgGrid2D();
00117
```

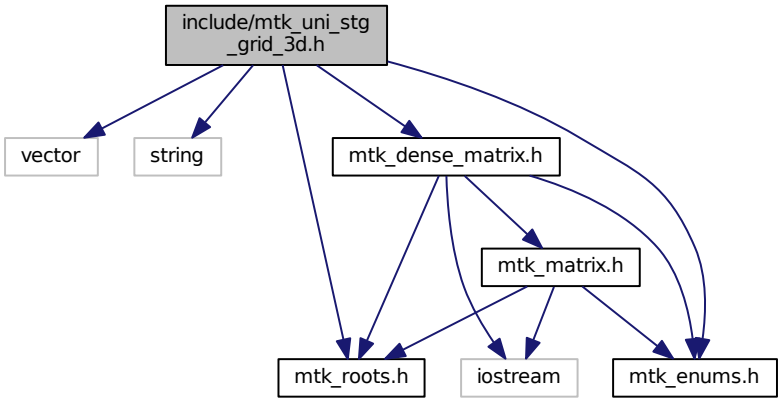
```
00125   const Real *discrete_domain_x() const;
00126
00134   const Real *discrete_domain_y() const;
00135
00141   Real *discrete_field();
00142
00150   FieldNature nature() const;
00151
00157   Real west_bndy() const;
00158
00164   Real east_bndy() const;
00165
00171   int num_cells_x() const;
00172
00178   Real delta_x() const;
00179
00185   Real south_bndy() const;
00186
00192   Real north_bndy() const;
00193
00199   int num_cells_y() const;
00200
00206   Real delta_y() const;
00207
00213   bool Bound() const;
00214
00220   int Size() const;
00221
00227   void BindScalarField(Real (*ScalarField)(const Real &xx, const
      Real &yy));
00228
00242   void BindVectorField(Real (*VectorFieldPComponent)(const
      Real &xx,
00243                                                      const Real &yy),
00244                        Real (*VectorFieldQComponent)(const Real &xx,
00245                                                      const Real &yy));
00246
00259   bool WriteToFile(std::string filename,
00260                    std::string space_name_x,
00261                    std::string space_name_y,
00262                    std::string field_name) const;
00263
00264  private:
00276   void BindVectorFieldPComponent(
00277     Real (*VectorFieldPComponent)(const Real &xx, const Real &yy));
00278
00290   void BindVectorFieldQComponent(
00291     Real (*VectorFieldQComponent)(const Real &xx, const Real &yy));
00292
00293   std::vector<Real> discrete_domain_x_;
00294   std::vector<Real> discrete_domain_y_;
00295   std::vector<Real> discrete_field_;
00296
00297   FieldNature nature_;
00298
00299   Real west_bndy_;
00300   Real east_bndy_;
00301   int num_cells_x_;
00302   Real delta_x_;
00303
00304   Real south_bndy_;
00305   Real north_bndy_;
00306   int num_cells_y_;
00307   Real delta_y_;
00308 };
00309 }
00310 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_2D_H_
```

18.77 include/mtk_uni_stg_grid_3d.h File Reference

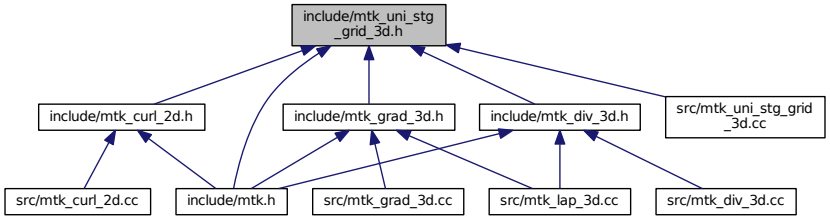
Definition of an 3D uniform staggered grid.

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

Include dependency graph for mtk_uni_stg_grid_3d.h:



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



Classes

- class mtk::UniStgGrid3D

  Uniform 3D Staggered Grid.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

18.77.1 Detailed Description

Definition of an 3D uniform staggered grid.

Author

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

Todo Create overloaded binding routines that read data from files.

Definition in file mtk_uni_stg_grid_3d.h.

18.78 mtk_uni_stg_grid_3d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
00035
00036 5. Neither the name of the copyright holder nor the names of its contributors
00037 may be used to endorse or promote products derived from this software without
00038 specific prior written permission.
00039
00040 The copyright holders provide no reassurances that the source code provided does
00041 not infringe any patent, copyright, or any other intellectual property rights of
00042 third parties. The copyright holders disclaim any liability to any recipient for
00043 claims brought against recipient by any third party for infringement of that
00044 parties intellectual property rights.
00045
00046 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00047 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00048 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00049 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00050 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00051 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00052 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_3D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_3D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_enums.h"
00066 #include "mtk_dense_matrix.h"
00067
00068 namespace mtk {
```

```
00069
00079 class UniStgGrid3D {
00080  public:
00082   friend std::ostream& operator <<(std::ostream& stream, UniStgGrid3D &in);
00083
00091   UniStgGrid3D operator=(const UniStgGrid3D &in);
00092
00094   UniStgGrid3D();
00095
00101   UniStgGrid3D(const UniStgGrid3D &grid);
00102
00119   UniStgGrid3D(const Real &west_bndy_x,
00120                const Real &east_bndy_x,
00121                const int &num_cells_x,
00122                const Real &south_bndy_y,
00123                const Real &north_bndy_y,
00124                const int &num_cells_y,
00125                const Real &bottom_bndy_z,
00126                const Real &top_bndy_z,
00127                const int &num_cells_z,
00128                const mtk::FieldNature &nature =
      mtk::FieldNature::SCALAR);
00129
00131   ~UniStgGrid3D();
00132
00140   const Real *discrete_domain_x() const;
00141
00149   const Real *discrete_domain_y() const;
00150
00158   const Real *discrete_domain_z() const;
00159
00165   Real *discrete_field();
00166
00174   FieldNature nature() const;
00175
00181   Real west_bndy() const;
00182
00188   Real east_bndy() const;
00189
00195   int num_cells_x() const;
00196
00202   Real delta_x() const;
00203
00209   Real south_bndy() const;
00210
00216   Real north_bndy() const;
00217
00223   int num_cells_y() const;
00224
00230   Real delta_y() const;
00231
00237   Real bottom_bndy() const;
00238
00244   Real top_bndy() const;
00245
00251   int num_cells_z() const;
00252
00258   Real delta_z() const;
00259
00265   bool Bound() const;
00266
00272   int Size() const;
00273
00279   void BindScalarField(
00280     Real (*ScalarField)(const Real &xx, const Real &yy, const Real &zz));
00281
00298   void BindVectorField(Real (*VectorFieldPComponent)(const
      Real &xx,
00299                                                      const Real &yy,
00300                                                      const Real &zz),
00301                        Real (*VectorFieldQComponent)(const Real &xx,
00302                                                      const Real &yy,
00303                                                      const Real &zz),
00304                        Real (*VectorFieldRComponent)(const Real &xx,
00305                                                      const Real &yy,
00306                                                      const Real &zz));
00307
00321   bool WriteToFile(std::string filename,
00322                    std::string space_name_x,
00323                    std::string space_name_y,
00324                    std::string space_name_z,
```

```
00325                   std::string field_name) const;
00326
00327  private:
00340   void BindVectorFieldPComponent(
00341     Real (*VectorFieldPComponent)(const Real &xx,
00342                                   const Real &yy,
00343                                   const Real &zz));
00344
00357   void BindVectorFieldQComponent(
00358     Real (*VectorFieldQComponent)(const Real &xx,
00359                                   const Real &yy,
00360                                   const Real &zz));
00361
00374   void BindVectorFieldRComponent(
00375     Real (*VectorFieldRComponent)(const Real &xx,
00376                                   const Real &yy,
00377                                   const Real &zz));
00378
00379   std::vector<Real> discrete_domain_x_;
00380   std::vector<Real> discrete_domain_y_;
00381   std::vector<Real> discrete_domain_z_;
00382   std::vector<Real> discrete_field_;
00383
00384   FieldNature nature_;
00385
00386   Real west_bndy_;
00387   Real east_bndy_;
00388   int num_cells_x_;
00389   Real delta_x_;
00390
00391   Real south_bndy_;
00392   Real north_bndy_;
00393   int num_cells_y_;
00394   Real delta_y_;
00395
00396   Real bottom_bndy_;
00397   Real top_bndy_;
00398   int num_cells_z_;
00399   Real delta_z_;
00400 };
00401 }
00402 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_3D_H_
```

18.79 Makefile.inc File Reference

18.80 Makefile.inc

```
00001 # Makefile setup file for the MTK.
00002
00003 SHELL := /bin/bash
00004
00005 #   1. Absolute path to base directory of the MTK.
00006 #   ___________________________________________________________________
00007
00008 BASE = /home/esanchez/Dropbox/MTK
00009
00010 #   2. The machine (platform) identifier and required machine precision.
00011 #   ___________________________________________________________________
00012
00013 # Options are:
00014 # - LINUX: A LINUX box installation.
00015 # - OSX: Uses OS X optimized solvers.
00016
00017 PLAT = LINUX
00018
00019 # Options are:
00020 # - SINGLE: Use 4 B floating point numbers.
00021 # - DOUBLE: Use 8 B floating point numbers.
00022
00023 PRECISION = DOUBLE
00024
00025 #   3. Optimized solvers and operations by means of ATLAS in Linux?
00026 #   ___________________________________________________________________
00027
00028 # If you have selected OSX in step 1, then you don't need to worry about this.
```

```
00029
00030 # Options are ON xor OFF:
00031
00032 ATL_OPT = OFF
00033
00034 #   4. Paths to dependencies (header files for compiling).
00035 #   ____________________________________________________________________
00036
00037 # GLPK include path (soon to go):
00038
00039 GLPK_INC = $(HOME)/Libraries/glpk-4.35/include
00040
00041 # Linux: If ATLAS optimization is ON, users should only provide the path to
00042 # ATLAS:
00043
00044 ATLAS_INC = $(HOME)/Libraries/ATLAS_3.8.4-CORE/include
00045
00046 # OS X: Do nothing.
00047
00048 #   5. Paths to dependencies (archive files for (static) linking).
00049 #   ____________________________________________________________________
00050
00051 # GLPK linking path (soon to go):
00052
00053 GLPK_LIB = $(HOME)/Libraries/glpk-4.35/lib/lib64/libglpk.a
00054
00055 # If optimization is OFF, then provide the paths for:
00056
00057 BLAS_LIB = $(HOME)/Libraries/BLAS-3.5.0/libblas.a
00058 LAPACK_LIB = $(HOME)/Libraries/lapack-3.5.0/liblapack.a
00059
00060 # WARNING: Vendor libraries should be used whenever they are available.
00061
00062 # However, if optimization is ON, please provide the path the ATLAS' archive:
00063
00064 ATLAS_LIB   = $(HOME)/Libraries/ATLAS_3.8.4-CORE/ATLAS_3.8.4-BUILD-Citadel/lib
00065
00066 #   6. Compiler and its flags.
00067 #   ____________________________________________________________________
00068
00069 CC = g++
00070
00071 # Selective Verbose Execution for Quick Debugging. Options are defined per
00072 # concern, and per data hierarchy on each concern.
00073
00074 # 0: NO verbose at all.
00075
00076 # 1: Enable verbose down to the 7th concern: messages.
00077 # 2: Enable verbose down to the 7th concern: messages + scalar results.
00078 # 3: Enable verbose down to the 7th concern. 1.1. + array results.
00079 # 4: Enable verbose down to the 7th concern. 1.2. + matrix results.
00080
00081 # 5: Enable verbose down to the 6th concern: messages.
00082 # 6: Enable verbose down to the 6th concern: messages + scalar results.
00083 # 7: Enable verbose down to the 6th concern. 2.1. + array results.
00084 # 8: Enable verbose down to the 6th concern. 2.2. + matrix results.
00085
00086 # 9: Enable verbose down to the 5th concern: messages.
00087 # 10: Enable verbose down to the 5th concern: messages + scalar results.
00088 # 11: Enable verbose down to the 5th concern. 3.1. + array results.
00089 # 12: Enable verbose down to the 5th concern. 3.2. + matrix results.
00090
00091 # 13: Enable verbose down to the 4th concern: messages.
00092 # 14: Enable verbose down to the 4th concern: messages + scalar results.
00093 # 15: Enable verbose down to the 4th concern. 4.1. + array results.
00094 # 16: Enable verbose down to the 4th concern. 4.2. + matrix results.
00095
00096 VERBOSE_LEVEL = 16
00097
00098 # Enable preventions. In the MTK, methods first validate their required
00099 # pre-conditions in run-time. Similarly, in many points throughout the MTK
00100 # codebase, different sanity checks are performed, as well. If this symbol is
00101 # defined to be 0, the MTK will # perform no validations to enhance execution
00102 # performance. Options are:
00103 # - YES.
00104 # - NO.
00105
00106 PERFORM_PREVENTIONS = YES
00107
00108 # Enables creation of LaTeX tables verbosing the computation of mimetic weights.
00109
```

```
00110 VERBOSE_WEIGHTS = YES
00111
00112 # Flags recommended for release code:
00113
00114 CCFLAGS = -Wall -Werror -O2
00115
00116 # Flags recommended for debugging code:
00117
00118 CCFLAGS = -Wall -Werror -g
00119
00120 #   7. Archiver, its flags, and ranlib:
00121 #   ___________________________________________________________________
00122
00123 ARCH      = ar
00124 ARCHFLAGS = cr
00125
00126 # If your system does not have "ranlib" then set: "RANLIB = echo":
00127
00128 RANLIB = echo
00129
00130 # But, if possible:
00131
00132 RANLIB = ranlib
00133
00134 #   8. Valgrind's memcheck options (optional):
00135 #   ___________________________________________________________________
00136
00137 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00138   --track-origins=yes --freelist-vol=20000000
00139
00140 # Done! User, please, do not mess with the definitions from this point on.
00141
00142 #   ___________________________________________________________________
00143 #   ___________________________________________________________________
00144 #   ___________________________________________________________________
00145
00146 #   MTK-related.
00147 #   ___________________________________________________________________
00148
00149 SRC       = $(BASE)/src
00150 INCLUDE   = $(BASE)/include
00151 LIB       = $(BASE)/lib
00152 MTK_LIB   = $(LIB)/libmtk.a
00153 TESTS     = $(BASE)/tests
00154 EXAMPLES  = $(BASE)/examples
00155
00156 #   Compiling-related.
00157 #   ___________________________________________________________________
00158
00159 CCFLAGS += -std=c++11 -fPIC \
00160   -DMTK_VERBOSE_LEVEL=$(VERBOSE_LEVEL) -I$(INCLUDE) -c
00161
00162 ifeq ($(PRECISION),DOUBLE)
00163   CCFLAGS += -DMTK_PRECISION_DOUBLE
00164 else
00165   CCFLAGS += -DMTK_PRECISION_SINGLE
00166 endif
00167
00168 ifeq ($(PERFORM_PREVENTIONS),YES)
00169   CCFLAGS += -DMTK_PERFORM_PREVENTIONS
00170 endif
00171
00172 ifeq ($(VERBOSE_WEIGHTS),YES)
00173   CCFLAGS += -DMTK_VERBOSE_WEIGHTS
00174 endif
00175
00176 # Only the GLPK is included because the other dependencies are coded in Fortran.
00177
00178 ifeq ($(ATL_OPT),ON)
00179   CCFLAGS  += -I$(GLPK_INC) $(ATLAS_INC)
00180 else
00181   CCFLAGS  += -I$(GLPK_INC)
00182 endif
00183
00184 #   Linking-related.
00185 #   ___________________________________________________________________
00186
00187 NOOPT_LIBS  = $(LAPACK_LIB) $(BLAS_LIB) -lm $(GLPK_LIB) -lstdc++
00188
00189 OPT_LIBS    = -L$(ATLAS_LIB) -latlas -llapack -lblas -lm -latlas -lstdc++
00190
```

```
00191 ifeq ($(PLAT),OSX)
00192   LINKER  = g++
00193   LINKER  += -framework Accelerate $(GLPK_LIB) $(MTK_LIB)
00194 else
00195   ifeq ($(ATL_OPT),ON)
00196     LINKER  = g++
00197     LIBS = $(MTK_LIB)
00198     LIBS += $(OPT_LIBS)
00199   else
00200     LINKER  = gfortran
00201     LIBS = $(MTK_LIB)
00202     LIBS += $(NOOPT_LIBS)
00203   endif
00204 endif
00205
00206 #   Documentation-related.
00207 #   ____________________________________________________________________
00208
00209 DOCGEN      = doxygen
00210 DOCFILENAME = doc_config.dxcf
00211 DOC         = $(BASE)/doc
00212 DOCFILE     = $(BASE)/$(DOCFILENAME)
```

18.81 README.md File Reference

18.82 README.md

```
00001 # The Mimetic Methods Toolkit (MTK)
00002
00003 By: **Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu**
00004
00005 ## 1. Description
00006
00007 We define numerical methods that are based on discretizations preserving the
00008 properties of their continuous counterparts to be **mimetic**.
00009
00010 The **Mimetic Methods Toolkit (MTK)** is a C++11 library for mimetic numerical
00011 methods. It is a set of classes for **mimetic interpolation**, **mimetic
00012 quadratures**, and **mimetic finite difference** methods for the **numerical
00013 solution of ordinary and partial differential equations**.
00014
00015 ## 2. Dependencies
00016
00017 This README file assumes all of these dependencies are installed in the
00018 following folder:
00019
00020 ```
00021 $(HOME)/Libraries/
00022 ```
00023
00024 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00025 routines for the internal computation on some of the layers. However, ATLAS
00026 requires both BLAS and LAPACK in order to create their optimized distributions.
00027 Therefore, the following dependencies tree arises:
00028
00029 ### For Linux:
00030
00031 1. LAPACK - Available from: http://www.netlib.org/lapack/
00032   1. BLAS - Available from: http://www.netlib.org/blas/
00033
00034 2. GLPK - Available from: https://www.gnu.org/software/glpk/
00035
00036 3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00037   1. LAPACK - Available from: http://www.netlib.org/lapack/
00038     1. BLAS - Available from: http://www.netlib.org/blas
00039
00040 4. (Optional) Valgrind - Available from: http://valgrind.org/
00041
00042 5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00043
00044 ### For OS X:
00045
00046 1. GLPK - Available from: https://www.gnu.org/software/glpk/
00047
00048 ## 3. Installation
```

```
00049
00050 ### PART 1. CONFIGURATION OF THE MAKEFILE.
00051
00052 The following steps are required to build and test the MTK. Please use the
00053 accompanying `Makefile.inc` file, which should provide a solid template to
00054 start with. The following command provides help on the options for make:
00055
00056 ```
00057 $ make help
00058 -----
00059 Makefile for the MTK.
00060
00061 Options are:
00062 - all: builds the library, the tests, and examples.
00063 - mtklib: builds the library.
00064 - test: builds the test files.
00065 - example: builds the examples.
00066
00067 - testall: runs all the tests.
00068
00069 - gendoc: generates the documentation for the library.
00070
00071 - clean: cleans all the generated files.
00072 - cleanlib: cleans the generated archive and object files.
00073 - cleantest: cleans the generated tests executables.
00074 - cleanexample: cleans the generated examples executables.
00075 -----
00076 ```
00077
00078 ### PART 2. BUILD THE LIBRARY.
00079
00080 ```
00081 $ make
00082 ```
00083
00084 If successful you'll read (before building the tests and examples):
00085 ```
00086 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
00087 ```
00088
00089 ## 4. Contact, Support, and Credits
00090
00091 The GitHub repository is: https://github.com/ejspeiro/MTK
00092
00093 The MTK is developed by researchers and adjuncts to the
00094 [Computational Science Research Center (CSRC)](http://www.csrc.sdsu.edu/)
00095 at [San Diego State University (SDSU)](http://www.sdsu.edu/).
00096
00097 Currently the developers are:
00098
00099 - **Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu** - @ejspeiro
00100 - Jose E. Castillo, PhD - jcastillo at mail dot sdsu dot edu
00101 - Guillermo F. Miranda, PhD - unigrav at hotmail dot com
00102 - Christopher P. Paolini, PhD - paolini at engineering dot sdsu dot edu
00103 - Angel Boada.
00104 - Johnny Corbino.
00105 - Raul Vargas-Navarro.
00106
00107 ### 4.1. Acknowledgements and Contributions
00108
00109 The authors would like to acknowledge valuable advising, feedback,
00110 and actual contributions from research personnel at the Computational Science
00111 Research Center (CSRC) at San Diego State University (SDSU). Their input was
00112 important to the fruition of this work. Specifically, our thanks go to
00113 (alphabetical order):
00114
00115 - Mohammad Abouali, PhD
00116 - Dany De Cecchis, PhD
00117 - Otilio Rojas, PhD
00118 - Julia Rossi.
00119
00120 ## 5. Referencing This Work
00121
00122 Please reference this work as follows:
00123 ```
00124 @article{Sanchez2014308,
00125   title = "The Mimetic Methods Toolkit: An object-oriented \{API\} for Mimetic
00126 Finite Differences ",
00127   journal = "Journal of Computational and Applied Mathematics ",
00128   volume = "270",
00129   number = "",
```

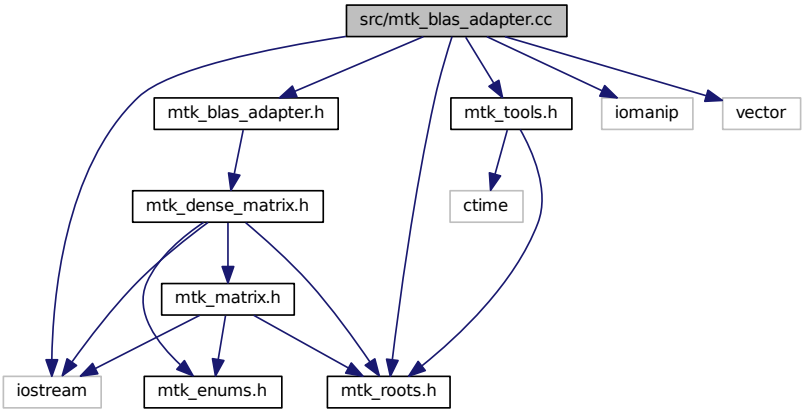
```
00130   pages = "308 - 322",
00131   year = "2014",
00132   note = "Fourth International Conference on Finite Element Methods in
00133 Engineering and Sciences (FEMTEC 2013) ",
00134   issn = "0377-0427",
00135   doi = "http://dx.doi.org/10.1016/j.cam.2013.12.046",
00136   url = "http://www.sciencedirect.com/science/article/pii/S037704271300719X",
00137   author = "Eduardo J. Sanchez and Christopher P. Paolini and Jose E. Castillo",
00138   keywords = "Object-oriented development",
00139   keywords = "Partial differential equations",
00140   keywords = "Application programming interfaces",
00141   keywords = "Mimetic Finite Differences "
00142 }
00143
00144 @Inbook{Sanchez2015,
00145   author="Sanchez, Eduardo and Paolini, Christopher and Blomgren, Peter
00146 and Castillo, Jose",
00147   editor="Kirby, M. Robert and Berzins, Martin and Hesthaven, S. Jan",
00148   chapter="Algorithms for Higher-Order Mimetic Operators",
00149   title="Spectral and High Order Methods for Partial Differential Equations
00150 ICOSAHOM 2014: Selected papers from the ICOSAHOM conference, June 23-27, 2014,
00151 Salt Lake City, Utah, USA",
00152   year="2015",
00153   publisher="Springer International Publishing",
00154   address="Cham",
00155   pages="425--434",
00156   isbn="978-3-319-19800-2",
00157   doi="10.1007/978-3-319-19800-2_39",
00158   url="http://dx.doi.org/10.1007/978-3-319-19800-2_39"
00159 }
00160 ```
00161
00162 Finally, please feel free to contact me with suggestions or corrections:
00163
00164 **Eduardo J. Sanchez, PhD - esanchez at mail dot sdsu dot edu** - @ejspeiro
00165
00166 Thanks and happy coding!
```

18.83 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)

18.83.1 Detailed Description

Implementation of a class that contains a collection of static member functions, 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

Todo Write documentation using LaTeX.

Author

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

Definition in file mtk_blas_adapter.cc.

18.84 mtk_blas_adapter.cc

```
00001
00027 /*
00028 Copyright (C) 2015, Computational Science Research Center, San Diego State
00029 University. All rights reserved.
00030
00031 Redistribution and use in source and binary forms, with or without modification,
00032 are permitted provided that the following conditions are met:
00033
00034 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00035 and a copy of the modified files should be reported once modifications are
00036 completed, unless these modifications are made through the project's GitHub
00037 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00038 should be developed and included in any deliverable.
00039
00040 2. Redistributions of source code must be done through direct
00041 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00042
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00070 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00071 */
00072
00073 #include <iostream>
00074 #include <iomanip>
00075
00076 #include <vector>
00077
00078 #include "mtk_roots.h"
00079 #include "mtk_tools.h"
00080 #include "mtk_blas_adapter.h"
00081
00082 namespace mtk {
00083
00084 extern "C" {
00085
00086 #ifdef MTK_PRECISION_DOUBLE
00087
00100 double dnrm2_(int *n, double *x, int *incx);
00101 #else
00102
00115 float snrm2_(int *n, float *x, int *incx);
00116 #endif
00117
```

```
00118 #ifdef MTK_PRECISION_DOUBLE
00119
00138 void daxpy_(int *n, double *da, double *dx, int *incx, double *dy, int *incy);
00139 #else
00140
00159 void saxpy_(int *n, float *sa, float *sx, int *incx, float *sy, int *incy);
00160 #endif
00161
00162 #ifdef MTK_PRECISION_DOUBLE
00163
00191 void dgemv_(char *trans,
00192             int *m,
00193             int *n,
00194             double *alpha,
00195             double *a,
00196             int *lda,
00197             double *x,
00198             int *incx,
00199             double *beta,
00200             double *y,
00201             int *incy);
00202 #else
00203
00231 void sgemv_(char *trans,
00232             int *m,
00233             int *n,
00234             float *alpha,
00235             float *a,
00236             int *lda,
00237             float *x,
00238             int *incx,
00239             float *beta,
00240             float *y,
00241             int *incy);
00242 #endif
00243
00244 #ifdef MTK_PRECISION_DOUBLE
00245
00270 void dgemm_(char *transa,
00271             char* transb,
00272             int *m,
00273             int *n,
00274             int *k,
00275             double *alpha,
00276             double *a,
00277             int *lda,
00278             double *b,
00279             int *ldb,
00280             double *beta,
00281             double *c,
00282             int *ldc);
00283 }
00284 #else
00285
00310 void sgemm_(char *transa,
00311             char* transb,
00312             int *m,
00313             int *n,
00314             int *k,
00315             double *alpha,
00316             double *a,
00317             int *lda,
00318             double *b,aamm
00319             int *ldb,
00320             double *beta,
00321             double *c,
00322             int *ldc);
00323 }
00324 #endif
00325 }
00326
00327 mtk::Real mtk::BLASAdapter::RealNRM2(Real *in, int &in_length) {
00328
00329   #ifdef MTK_PERFORM_PREVENTIONS
00330   mtk::Tools::Prevent(in_length <= 0, __FILE__, __LINE__, __func__);
00331   #endif
00332
00333   int incx{1};  // Increment for the elements of xx. ix >= 0.
00334
00335   #ifdef MTK_PRECISION_DOUBLE
00336   return dnrm2_(&in_length, in, &incx);
```

```
00337   #else
00338   return snrm2_(&in_length, in, &incx);
00339   #endif
00340 }
00341
00342 void mtk::BLASAdapter::RealAXPY(mtk::Real alpha,
00343                                 mtk::Real *xx,
00344                                 mtk::Real *yy,
00345                                 int &in_length) {
00346
00347   #ifdef MTK_PERFORM_PREVENTIONS
00348   mtk::Tools::Prevent(xx == nullptr, __FILE__, __LINE__, __func__);
00349   mtk::Tools::Prevent(yy == nullptr, __FILE__, __LINE__, __func__);
00350   #endif
00351
00352   int incx{1};  // Increment for the elements of xx. ix >= 0.
00353
00354   #ifdef MTK_PRECISION_DOUBLE
00355   daxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00356   #else
00357   saxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00358   #endif
00359 }
00360
00361 mtk::Real mtk::BLASAdapter::RelNorm2Error(
      mtk::Real *computed,
00362                                       mtk::Real *known,
00363                                       int length) {
00364
00365   #ifdef MTK_PERFORM_PREVENTIONS
00366   mtk::Tools::Prevent(computed == nullptr, __FILE__, __LINE__, __func__);
00367   mtk::Tools::Prevent(known == nullptr, __FILE__, __LINE__, __func__);
00368   #endif
00369
00370   mtk::Real norm_2_computed{mtk::BLASAdapter::RealNRM2(known, length)};
00371
00372   mtk::Real alpha{-mtk::kOne};
00373
00374   mtk::BLASAdapter::RealAXPY(alpha, known, computed, length);
00375
00376   mtk::Real norm_2_difference{mtk::BLASAdapter::RealNRM2(computed,
      length)};
00377
00378   return norm_2_difference/norm_2_computed;
00379 }
00380
00381 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00382                                    mtk::DenseMatrix &aa,
00383                                    mtk::Real *xx,
00384                                    mtk::Real &beta,
00385                                    mtk::Real *yy) {
00386
00387   // Make sure input matrices are row-major ordered.
00388
00389   if (aa.matrix_properties().ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00390     aa.OrderRowMajor();
00391   }
00392
00393   char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00394
00395   int mm{aa.num_rows()};                  // Rows of aa.
00396   int nn{aa.num_cols()};                  // Columns of aa.
00397   int lda{(aa.matrix_properties()).ld()}; // Leading dimension.
00398   int incx{1};                            // Increment of values in x.
00399   int incy{1};                            // Increment of values in y.
00400
00401   std::swap(mm,nn);
00402   #ifdef MTK_PRECISION_DOUBLE
00403   dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00404          xx, &incx, &beta, yy, &incy);
00405   #else
00406   sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00407         xx, &incx, &beta, yy, &incy);
00408   #endif
00409   std::swap(mm,nn);
00410 }
00411
00412 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
      mtk::DenseMatrix &aa,
00413                                               mtk::DenseMatrix &bb) {
```

```
00414
00415   #ifdef MTK_PERFORM_PREVENTIONS
00416   mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00417                       __FILE__, __LINE__, __func__);
00418   #endif
00419
00421   if (aa.matrix_properties().ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00422     aa.OrderRowMajor();
00423   }
00424   if (bb.matrix_properties().ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00425     bb.OrderRowMajor();
00426   }
00427
00429   char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00430   char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00431
00432   int mm{aa.num_rows()};  // Rows of aa and rows of cc.
00433   int nn{bb.num_cols()};  // Cols of bb and cols of cc.
00434   int kk{aa.num_cols()};  // Cols of aa and rows of bb.
00435
00436   int cc_num_rows{mm};  // Rows of cc.
00437   int cc_num_cols{nn};  // Columns of cc.
00438
00439   int lda{std::max(1,kk)};  // Leading dimension of the aa matrix.
00440   int ldb{std::max(1,nn)};  // Leading dimension of the bb matrix.
00441   int ldc{std::max(1,mm)};  // Leading dimension of the cc matrix.
00442
00443   mtk::Real alpha{mtk::kOne}; // First scalar coefficient.
00444   mtk::Real beta{mtk::kZero}; // Second scalar coefficient.
00445
00446   mtk::DenseMatrix cc_col_maj_ord(cc_num_rows,cc_num_cols); // Output matrix.
00447
00448   cc_col_maj_ord.SetOrdering(mtk::MatrixOrdering::COL_MAJOR);
00449
00451   #ifdef MTK_PRECISION_DOUBLE
00452   dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00453          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00454   #else
00455   sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00456          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00457   #endif
00458
00459   #if MTK_VERBOSE_LEVEL > 12
00460   std::cout << "cc_col_maj_ord =" << std::endl;
00461   std::cout << cc_col_maj_ord << std::endl;
00462   #endif
00463
00464   cc_col_maj_ord.OrderRowMajor();
00465
00466   return cc_col_maj_ord;
00467 }
00468
00469 mtk::DenseMatrix mtk::BLASAdapter::RealDenseSM(
      mtk::Real alpha,
00470                                                mtk::DenseMatrix &aa) {
00471
00472   #ifdef MTK_PERFORM_PREVENTIONS
00473   mtk::Tools::Prevent(aa.num_rows() == 0, __FILE__, __LINE__, __func__);
00474   mtk::Tools::Prevent(aa.num_cols() == 0, __FILE__, __LINE__, __func__);
00475   #endif
00476
00478   if (aa.matrix_properties().ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00479     aa.OrderRowMajor();
00480   }
00481
00483   char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00484   char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00485
00486   int mm{aa.num_rows()};  // Rows of aa and rows of cc.
00487   int nn{aa.num_cols()};  // Cols of bb and cols of cc.
00488   int kk{aa.num_cols()};  // Cols of aa and rows of bb.
00489
00490   int lda{std::max(1,kk)};  // Leading dimension of the aa matrix.
00491   int ldb{std::max(1,nn)};  // Leading dimension of the bb matrix.
00492   int ldc{std::max(1,mm)};  // Leading dimension of the cc matrix.
00493
00494   mtk::Real beta{alpha}; // Second scalar coefficient.
00495
```

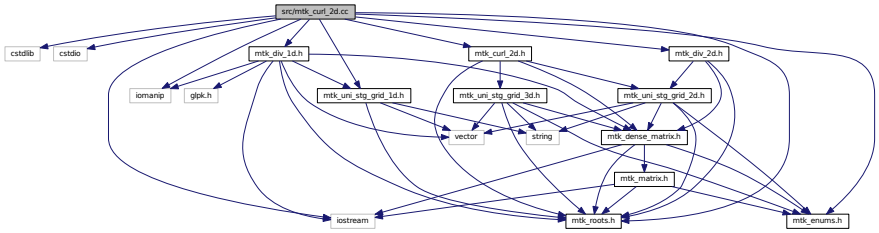
```
00496   alpha = mtk::kZero;
00497
00498   mtk::DenseMatrix alpha_aa(aa); // Output matrix.
00499
00501   #ifdef MTK_PRECISION_DOUBLE
00502   dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00503          aa.data(), &ldb, &beta, alpha_aa.data(), &ldc);
00504   #else
00505   sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00506          aa.data(), &ldb, &beta, alpha_aa.data(), &ldc);
00507   #endif
00508
00509   #if MTK_VERBOSE_LEVEL > 12
00510   std::cout << "alpha_aa =" << std::endl;
00511   std::cout << alpha_aa << std::endl;
00512   #endif
00513
00514   return alpha_aa;
00515 }
```

18.85 src/mtk_curl_2d.cc File Reference

Implements the class Curl2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_div_1d.h"
#include "mtk_div_2d.h"
#include "mtk_curl_2d.h"
```

Include dependency graph for mtk_curl_2d.cc:



18.85.1 Detailed Description

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

Author

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

Definition in file mtk_curl_2d.cc.

18.86 mtk_curl_2d.cc

```
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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
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00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_1d.h"
00066 #include "mtk_div_1d.h"
00067 #include "mtk_div_2d.h"
00068 #include "mtk_curl_2d.h"
00069
00070 mtk::UniStgGrid3D mtk::Curl2D::operator*(const
      mtk::UniStgGrid2D &grid) const {
00071
00073
00074   mtk::UniStgGrid3D output;
00075
00076   return output;
00077 }
00078
00079 mtk::Curl2D::Curl2D():
00080   order_accuracy_(),
00081   mimetic_threshold_() {}
00082
00083 mtk::Curl2D::Curl2D(const Curl2D &curl):
00084   order_accuracy_(curl.order_accuracy_),
00085   mimetic_threshold_(curl.mimetic_threshold_) {}
00086
00087 mtk::Curl2D::~Curl2D() {}
```
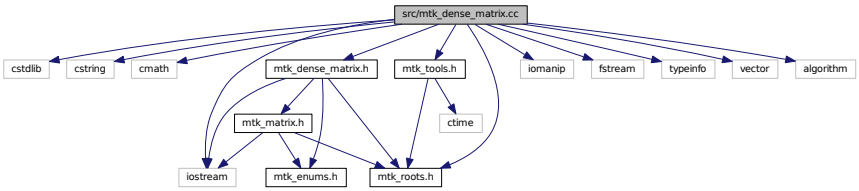

```
00088
00089 bool mtk::Curl2D::ConstructCurl2D(const
      mtk::UniStgGrid2D &grid,
00090                                  int order_accuracy,
00091                                  mtk::Real mimetic_threshold) {
00092
00093   int num_cells_x = grid.num_cells_x();
00094   int num_cells_y = grid.num_cells_y();
00095
00096   int mx = num_cells_x + 2;  // Dx vertical dimension.
00097   int nx = num_cells_x + 1;  // Dx horizontal dimension.
00098   int my = num_cells_y + 2;  // Dy vertical dimension.
00099   int ny = num_cells_y + 1;  // Dy horizontal dimension.
00100
00101   mtk::Div1D div;
00102
00103   bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00104
00105   #ifdef MTK_PERFORM_PREVENTIONS
00106   if (!info) {
00107     std::cerr << "Mimetic div could not be built." << std::endl;
00108     return info;
00109   }
00110   #endif
00111
00112   auto west = grid.west_bndy();
00113   auto east = grid.east_bndy();
00114   auto south = grid.south_bndy();
00115   auto north = grid.east_bndy();
00116
00117   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00118   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00119
00120   mtk::DenseMatrix dx(div.ReturnAsDenseMatrix(grid_x));
00121   mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00122
00123   bool padded{true};
00124   bool transpose{false};
00125
00126   mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00127   mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00128
00129   mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00130   mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00131
00132   #if MTK_VERBOSE_LEVEL > 2
00133   std::cout << "Dx: " << mx << " by " << nx << std::endl;
00134   std::cout << "Iy : " << num_cells_y<< " by " << ny  << std::endl;
00135   std::cout << "Dy: " << my << " by " << ny << std::endl;
00136   std::cout << "Ix : " << num_cells_x<< " by " << nx  << std::endl;
00137   std::cout << "Curl 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00138     nx*ny <<std::endl;
00139   #endif
00140
00141   mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00142
00143   for (auto ii = 0; ii < mx*my; ii++) {
00144     for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00145       d2d.SetValue(ii, jj, dxy.GetValue(ii,jj));
00146     }
00147     for(auto kk=0; kk<ny*num_cells_x; kk++) {
00148       d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00149     }
00150   }
00151
00152   curl_ = d2d;
00153
00154   return info;
00155 }
00156
00157 mtk::DenseMatrix mtk::Curl2D::ReturnAsDenseMatrix() const {
00158
00159   return curl_;
00160 }
```

18.87 src/mtk_dense_matrix.cc File Reference

```
#include <cstdlib>
#include <cstring>
#include <cmath>
#include <iostream>
#include <iomanip>
#include <fstream>
#include <typeinfo>
#include <vector>
#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)

18.88 mtk_dense_matrix.cc

```
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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
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```

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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 <vector>
00070
00071 #include <algorithm>
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075 #include "mtk_tools.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00080
00081   int mm{in.matrix_properties_.num_rows()};  // Auxiliary.
00082   int nn{in.matrix_properties_.num_cols()};  // Auxiliary.
00083   int output_precision{4};
00084   int output_width{10};
00085
00086   if (in.matrix_properties_.ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00087     std::swap(mm, nn);
00088   }
00089   for (int ii = 0; ii < mm; ii++) {
00090     int offset{ii*nn};
00091     for (int jj = 0; jj < nn; jj++) {
00092       mtk::Real value = in.data_[offset + jj];
00093       stream << std::setprecision(output_precision) <<
00094         std::setw(output_width) << value;
00095     }
00096     stream << std::endl;
00097   }
00098   if (in.matrix_properties_.ordering() ==
      mtk::MatrixOrdering::COL_MAJOR) {
00099     std::swap(mm, nn);
00100   }
00101   return stream;
00102 }
00103 }
00104
00105 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
      mtk::DenseMatrix &in) {
00106
00107   if(this == &in) {
00108     return *this;
00109   }
```

```
00110
00111   matrix_properties_.set_storage(in.
      matrix_properties_.storage());
00112
00113   matrix_properties_.set_ordering(in.
      matrix_properties_.ordering());
00114
00115   auto aux = in.matrix_properties_.num_rows();
00116   matrix_properties_.set_num_rows(aux);
00117
00118   aux = in.matrix_properties().num_cols();
00119   matrix_properties_.set_num_cols(aux);
00120
00121   aux = in.matrix_properties().num_zero();
00122   matrix_properties_.set_num_zero(aux);
00123
00124   aux = in.matrix_properties().num_null();
00125   matrix_properties_.set_num_null(aux);
00126
00127   auto num_rows = matrix_properties_.num_rows();
00128   auto num_cols = matrix_properties_.num_cols();
00129
00130   delete [] data_;
00131
00132   try {
00133     data_ = new mtk::Real[num_rows*num_cols];
00134   } catch (std::bad_alloc &memory_allocation_exception) {
00135     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00136       std::endl;
00137     std::cerr << memory_allocation_exception.what() << std::endl;
00138   }
00139   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*
      num_cols);
00140
00141   std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00142
00143   return *this;
00144 }
00145
00146 bool mtk::DenseMatrix::operator ==(const
      DenseMatrix &in) {
00147
00148   bool ans{true};
00149
00150   auto mm = in.num_rows();
00151   auto nn = in.num_cols();
00152
00153   if (mm != matrix_properties_.num_rows() ||
00154       nn != matrix_properties_.num_cols()) {
00155     return false;
00156   }
00157
00158   for (int ii = 0; ii < mm && ans; ++ii) {
00159     for (int jj = 0; jj < nn && ans; ++jj) {
00160       ans = ans &&
00161         abs(data_[ii*nn + jj] - in.data()[ii*nn + jj]) <
      mtk::kDefaultTolerance;
00162     }
00163   }
00164   return ans;
00165 }
00166
00167 mtk::DenseMatrix::DenseMatrix(): data_(nullptr) {
00168
00169   matrix_properties_.set_storage(
      mtk::MatrixStorage::DENSE);
00170   matrix_properties_.set_ordering(
      mtk::MatrixOrdering::ROW_MAJOR);
00171 }
00172
00173 mtk::DenseMatrix::DenseMatrix(const
      mtk::DenseMatrix &in) {
00174
00175   matrix_properties_.set_storage(in.matrix_properties_.storage());
00176
00177   matrix_properties_.set_ordering(in.matrix_properties_.
      ordering());
00178
00179   auto aux = in.matrix_properties_.num_rows();
00180   matrix_properties_.set_num_rows(aux);
00181
```

```
00182   aux = in.matrix_properties().num_cols();
00183   matrix_properties_.set_num_cols(aux);
00184
00185   aux = in.matrix_properties().num_zero();
00186   matrix_properties_.set_num_zero(aux);
00187
00188   aux = in.matrix_properties().num_null();
00189   matrix_properties_.set_num_null(aux);
00190
00191   auto num_rows = in.matrix_properties_.num_rows();
00192   auto num_cols = in.matrix_properties_.num_cols();
00193
00194   try {
00195     data_ = new mtk::Real[num_rows*num_cols];
00196   } catch (std::bad_alloc &memory_allocation_exception) {
00197     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00198       std::endl;
00199     std::cerr << memory_allocation_exception.what() << std::endl;
00200   }
00201   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00202
00203   std::copy(in.data_,in.data_ + num_rows*num_cols,data_);
00204 }
00205
00206 mtk::DenseMatrix::DenseMatrix(const int &num_rows, const int &num_cols) {
00207
00208   #ifdef MTK_PERFORM_PREVENTIONS
00209   mtk::Tools::Prevent(num_rows < 1, __FILE__, __LINE__, __func__);
00210   mtk::Tools::Prevent(num_cols < 1, __FILE__, __LINE__, __func__);
00211   #endif
00212
00213   matrix_properties_.set_storage(mtk::MatrixStorage::DENSE);
00214   matrix_properties_.set_ordering(mtk::MatrixOrdering::ROW_MAJOR);
00215   matrix_properties_.set_num_rows(num_rows);
00216   matrix_properties_.set_num_cols(num_cols);
00217
00218   try {
00219     data_ = new mtk::Real[num_rows*num_cols];
00220   } catch (std::bad_alloc &memory_allocation_exception) {
00221     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00222       std::endl;
00223     std::cerr << memory_allocation_exception.what() << std::endl;
00224   }
00225   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00226 }
00227
00228 mtk::DenseMatrix::DenseMatrix(const int &rank,
00229                               const bool &padded,
00230                               const bool &transpose) {
00231
00232   #ifdef MTK_PERFORM_PREVENTIONS
00233   mtk::Tools::Prevent(rank < 1, __FILE__, __LINE__, __func__);
00234   #endif
00235
00236   int aux{};  // Used to control the padding.
00237
00238   if (padded) {
00239     aux = 1;
00240   }
00241
00242   matrix_properties_.set_storage(mtk::MatrixStorage::DENSE);
00243   matrix_properties_.set_ordering(mtk::MatrixOrdering::ROW_MAJOR);
00244   matrix_properties_.set_num_rows(aux + rank + aux);
00245   matrix_properties_.set_num_cols(rank);
00246
00247   try {
00248     data_ = new mtk::Real[matrix_properties_.num_values()];
00249   } catch (std::bad_alloc &memory_allocation_exception) {
00250     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00251       std::endl;
00252     std::cerr << memory_allocation_exception.what() << std::endl;
00253   }
00254   memset(data_,
00255          mtk::kZero,
00256          sizeof(data_[0])*(matrix_properties_.num_values()));
00257
00258   for (auto ii =0 ; ii < matrix_properties_.num_rows(); ++ii) {
00259     for (auto jj = 0; jj < matrix_properties_.num_cols(); ++jj) {
00260       data_[ii*matrix_properties_.num_cols() + jj] =
00261         (ii == jj + aux)? mtk::kOne: mtk::kZero;
00262     }
```

```
00263   }
00264   if (transpose) {
00265     Transpose();
00266   }
00267 }
00268
00269 mtk::DenseMatrix::DenseMatrix(const mtk::Real *const gen,
00270                               const int &gen_length,
00271                               const int &pro_length,
00272                               const bool &transpose) {
00273
00274   #ifdef MTK_PERFORM_PREVENTIONS
00275   mtk::Tools::Prevent(gen == nullptr, __FILE__, __LINE__, __func__);
00276   mtk::Tools::Prevent(gen_length < 1, __FILE__, __LINE__, __func__);
00277   mtk::Tools::Prevent(pro_length < 1, __FILE__, __LINE__, __func__);
00278   #endif
00279
00280   matrix_properties_.set_storage(mtk::MatrixStorage::DENSE);
00281   matrix_properties_.set_ordering(mtk::MatrixOrdering::ROW_MAJOR);
00282   if (!transpose) {
00283     matrix_properties_.set_num_rows(gen_length);
00284     matrix_properties_.set_num_cols(pro_length);
00285   } else {
00286     matrix_properties_.set_num_rows(pro_length);
00287     matrix_properties_.set_num_cols(gen_length);
00288   }
00289
00290   int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00291   int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00292
00293   try {
00294     data_ = new mtk::Real[mm*nn];
00295   } catch (std::bad_alloc &memory_allocation_exception) {
00296     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00297       std::endl;
00298     std::cerr << memory_allocation_exception.what() << std::endl;
00299   }
00300   memset(data_, mtk::kZero, sizeof(data_[0])*mm*nn);
00301
00302   if (!transpose) {
00303     for (auto ii = 0; ii < mm; ii++) {
00304       for (auto jj = 0; jj < nn; jj++) {
00305         data_[ii*nn + jj] = pow(gen[ii], (double) jj);
00306       }
00307     }
00308   } else {
00309     for (auto ii = 0; ii < mm; ii++) {
00310       for (auto jj = 0; jj < nn; jj++) {
00311         data_[ii*nn + jj] = pow(gen[jj], (double) ii);
00312       }
00313     }
00314   }
00315 }
00316
00317 mtk::DenseMatrix::~DenseMatrix() {
00318
00319   delete [] data_;
00320   data_ = nullptr;
00321 }
00322
00323 mtk::Matrix mtk::DenseMatrix::matrix_properties() const
      noexcept {
00324
00325   return matrix_properties_;
00326 }
00327
00328 void mtk::DenseMatrix::SetOrdering(
      mtk::MatrixOrdering oo) noexcept {
00329
00330   #ifdef MTK_PERFORM_PREVENTIONS
00331   mtk::Tools::Prevent(!(oo == mtk::MatrixOrdering::ROW_MAJOR
       || oo ==
00332 mtk::MatrixOrdering::COL_MAJOR),
00333                       __FILE__, __LINE__, __func__);
00334   #endif
00335
00336   matrix_properties_.set_ordering(oo);
00337 }
00338
00339 int mtk::DenseMatrix::num_rows() const noexcept {
00340
```

```
00341   return matrix_properties_.num_rows();
00342 }
00343
00344 int mtk::DenseMatrix::num_cols() const noexcept {
00345
00346   return matrix_properties_.num_cols();
00347 }
00348
00349 mtk::Real* mtk::DenseMatrix::data() const noexcept {
00350
00351   return data_;
00352 }
00353
00354 mtk::Real mtk::DenseMatrix::GetValue(
00355     const int &mm,
00356     const int &nn) const noexcept {
00357
00358   #ifdef MTK_PERFORM_PREVENTIONS
00359   mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00360   mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00361   #endif
00362
00363   return data_[mm*matrix_properties_.num_cols() + nn];
00364 }
00365
00366 void  mtk::DenseMatrix::SetValue(
00367     const int &mm,
00368     const int &nn,
00369     const mtk::Real &val) noexcept {
00370
00371   #ifdef MTK_PERFORM_PREVENTIONS
00372   mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00373   mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00374   #endif
00375
00376   data_[mm*matrix_properties_.num_cols() + nn] = val;
00377 }
00378
00379 void mtk::DenseMatrix::Transpose() {
00380
00382
00383   mtk::Real *data_transposed{}; // Buffer.
00384
00385   int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00386   int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00387
00388   try {
00389     data_transposed = new mtk::Real[mm*nn];
00390   } catch (std::bad_alloc &memory_allocation_exception) {
00391     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00392       std::endl;
00393     std::cerr << memory_allocation_exception.what() << std::endl;
00394   }
00395   memset(data_transposed,
00396          mtk::kZero,
00397          sizeof(data_transposed[0])*mm*nn);
00398
00399   // Assign the values to their transposed position.
00400   for (auto ii = 0; ii < mm; ++ii) {
00401     for (auto jj = 0; jj < nn; ++jj) {
00402       data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00403     }
00404   }
00405
00406   // Swap pointers.
00407   auto tmp = data_; // Temporal holder.
00408   data_ = data_transposed;
00409   delete [] tmp;
00410   tmp = nullptr;
00411
00412   matrix_properties_.set_num_rows(nn);
00413   matrix_properties_.set_num_cols(mm);
00414 }
00415
00416 void mtk::DenseMatrix::OrderRowMajor() {
00417
00418   if (matrix_properties_.ordering() == mtk::MatrixOrdering::COL_MAJOR) {
00419
00421
00422     mtk::Real *data_transposed{}; // Buffer.
00423
```

```
00424     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00425     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00426 
00427     try {
00428       data_transposed = new mtk::Real[mm*nn];
00429     } catch (std::bad_alloc &memory_allocation_exception) {
00430       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00431         std::endl;
00432       std::cerr << memory_allocation_exception.what() << std::endl;
00433     }
00434     memset(data_transposed,
00435           mtk::kZero,
00436           sizeof(data_transposed[0])*mm*nn);
00437 
00438     // Assign the values to their transposed position.
00439     std::swap(mm, nn);
00440     for (auto ii = 0; ii < mm; ++ii) {
00441       for (auto jj = 0; jj < nn; ++jj) {
00442         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00443       }
00444     }
00445     std::swap(mm, nn);
00446 
00447     // Swap pointers.
00448     auto tmp = data_; // Temporal holder.
00449     data_ = data_transposed;
00450     delete [] tmp;
00451     tmp = nullptr;
00452 
00453     matrix_properties_.set_ordering(mtk::MatrixOrdering::ROW_MAJOR);
00454   }
00455 }
00456 
00457 void mtk::DenseMatrix::OrderColMajor() {
00458 
00459   if (matrix_properties_.ordering() == mtk::MatrixOrdering::ROW_MAJOR) {
00460 
00462 
00463     mtk::Real *data_transposed{}; // Buffer.
00464 
00465     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00466     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00467 
00468     try {
00469       data_transposed = new mtk::Real[mm*nn];
00470     } catch (std::bad_alloc &memory_allocation_exception) {
00471       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00472         std::endl;
00473       std::cerr << memory_allocation_exception.what() << std::endl;
00474     }
00475     memset(data_transposed,
00476           mtk::kZero,
00477           sizeof(data_transposed[0])*mm*nn);
00478 
00479     // Assign the values to their transposed position.
00480     for (auto ii = 0; ii < mm; ++ii) {
00481       for (auto jj = 0; jj < nn; ++jj) {
00482         data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00483       }
00484     }
00485 
00486     // Swap pointers.
00487     auto tmp = data_; // Temporal holder.
00488     data_ = data_transposed;
00489     delete [] tmp;
00490     tmp = nullptr;
00491 
00492     matrix_properties_.set_ordering(mtk::MatrixOrdering::COL_MAJOR);
00493   }
00494 }
00495 
00496 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
      mtk::DenseMatrix &aa,
00497                                         const mtk::DenseMatrix &bb) {
00498 
00500 
00501   int row_offset{}; // Offset for rows.
00502   int col_offset{}; // Offset for rows.
00503 
00504   mtk::Real aa_factor{};    // Used in computation.
00505 
```

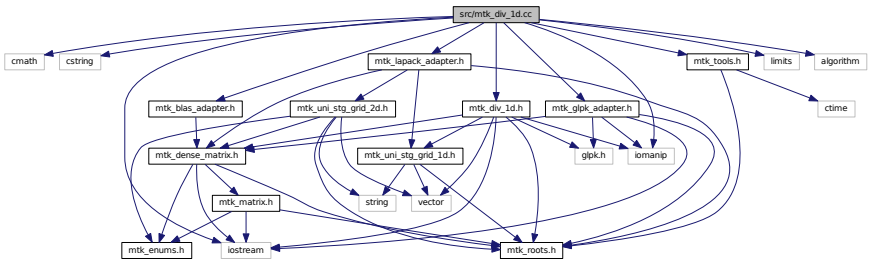
```
00506   // Auxiliary variables:
00507   auto aux1 = aa.matrix_properties_.num_rows()*bb.
      matrix_properties_.num_rows();
00508   auto aux2 = aa.matrix_properties_.num_cols()*bb.
      matrix_properties_.num_cols();
00509
00510   mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00511
00512   int kk_num_cols{output.matrix_properties_.num_cols()}; // Aux.
00513
00514   auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00515   auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00516   auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00517   auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00518
00519   for (auto ii = 0; ii < mm; ++ii) {
00520     row_offset = ii*pp;
00521     for (auto jj = 0; jj < nn; ++jj) {
00522       col_offset = jj*qq;
00523       aa_factor = aa.data_[ii*nn + jj];
00524       for (auto ll = 0; ll < pp; ++ll) {
00525         for (auto oo = 0; oo < qq; ++oo) {
00526           auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00527           output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00528         }
00529       }
00530     }
00531   }
00532
00533   output.matrix_properties_.set_storage(
      mtk::MatrixStorage::DENSE);
00534   output.matrix_properties_.set_ordering(
      mtk::MatrixOrdering::ROW_MAJOR);
00535
00536   return output;
00537 }
00538
00539 bool mtk::DenseMatrix::WriteToFile(const std::string &filename) const {
00540
00541   std::ofstream output_dat_file;  // Output file.
00542
00543   output_dat_file.open(filename);
00544
00545   if (!output_dat_file.is_open()) {
00546     return false;
00547   }
00548
00549   int mm{matrix_properties_.num_rows()};
00550   int nn{matrix_properties_.num_cols()};
00551
00552   for (int ii = 0; ii < mm; ++ii) {
00553     int offset{ii*nn};
00554     for (int jj = 0; jj < nn; ++jj) {
00555       output_dat_file << ii << ' ' << jj << ' ' << data_[offset + jj] <<
00556         std::endl;
00557     }
00558   }
00559
00560   output_dat_file.close();
00561
00562   return true;
00563 }
```

18.89 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)

18.89.1 Detailed Description

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

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Todo Overload ostream operator as in mtk::Lap1D.

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

Definition in file mtk_div_1d.cc.

18.90 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
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00033 other materials provided with the distribution.
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00048
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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
00067 #ifdef MTK_VERBOSE_WEIGHTS
00068 #include <fstream>
00069 #endif
00070
00071 #include <limits>
00072 #include <algorithm>
00073
00074 #include "mtk_tools.h"
00075
00076 #include "mtk_blas_adapter.h"
00077 #include "mtk_lapack_adapter.h"
00078 #include "mtk_glpk_adapter.h"
00079
00080 #include "mtk_div_1d.h"
00081
00082 namespace mtk {
00083
00084 std::ostream& operator <<(std::ostream &stream, mtk::Div1D &in) {
00085
00086   int output_precision{4};
00087   int output_width{8};
00088
00090
00091   stream << "Order of accuracy: " << in.divergence_[0] << std::endl;
00092
```

```
00094
00095   stream << "Interior stencil: " << std::endl;
00096   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00097     stream << std::setprecision(output_precision) << std::setw(output_width) <<
00098       in.divergence_[ii] << ' ';
00099   }
00100   stream << std::endl;
00101
00102   if (in.order_accuracy_ > 2) {
00103
00105
00106     stream << "Weights:" << std::endl;
00107     for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00108       stream << std::setprecision(output_precision) <<
00109         std::setw(output_width) << in.divergence_[ii] << ' ';
00110     }
00111     stream << std::endl;
00112
00114
00115     auto offset = (2*in.order_accuracy_ + 1);
00116     int mm{};
00117     for (auto ii = 0; ii < in.dim_null_; ++ii) {
00118       stream << "Boundary row " << ii + 1 << ":" << std::endl;
00119       for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00120         auto value = in.divergence_[offset + mm];
00121         stream << std::setprecision(output_precision) <<
00122           std::setw(output_width) << value << ' ';
00123         ++mm;
00124       }
00125       stream << std::endl;
00126       stream << "Sum of elements in boundary row " << ii + 1 << ": " <<
00127         in.sums_rows_mim_bndy_[ii];
00128       stream << std::endl;
00129     }
00130   }
00131
00132   return stream;
00133 }
00134 }
00135
00136 mtk::Div1D::Div1D():
00137   order_accuracy_(mtk::kDefaultOrderAccuracy),
00138   dim_null_(),
00139   num_bndy_coeffs_(),
00140   divergence_length_(),
00141   minrow_(),
00142   row_(),
00143   num_feasible_sols_(),
00144   coeffs_interior_(),
00145   prem_apps_(),
00146   weights_crs_(),
00147   weights_cbs_(),
00148   mim_bndy_(),
00149   divergence_(),
00150   mimetic_threshold_(mtk::kDefaultMimeticThreshold),
00151   mimetic_measure_(mtk::kZero),
00152   sums_rows_mim_bndy_() {}
00153
00154 mtk::Div1D::Div1D(const Div1D &div):
00155   order_accuracy_(div.order_accuracy_),
00156   dim_null_(div.dim_null_),
00157   num_bndy_coeffs_(div.num_bndy_coeffs_),
00158   divergence_length_(div.divergence_length_),
00159   minrow_(div.minrow_),
00160   row_(div.row_),
00161   num_feasible_sols_(div.num_feasible_sols_),
00162   coeffs_interior_(div.coeffs_interior_),
00163   prem_apps_(div.prem_apps_),
00164   weights_crs_(div.weights_crs_),
00165   weights_cbs_(div.weights_cbs_),
00166   mim_bndy_(div.mim_bndy_),
00167   divergence_(div.divergence_),
00168   mimetic_threshold_(div.mimetic_threshold_),
00169   mimetic_measure_(div.mimetic_measure_),
00170   sums_rows_mim_bndy_(div.sums_rows_mim_bndy_) {}
00171
00172 mtk::Div1D::~Div1D() {
00173
00174   delete[] coeffs_interior_;
00175   coeffs_interior_ = nullptr;
```

```
00176
00177   delete[] prem_apps_;
00178   prem_apps_ = nullptr;
00179
00180   delete[] weights_crs_;
00181   weights_crs_ = nullptr;
00182
00183   delete[] weights_cbs_;
00184   weights_cbs_ = nullptr;
00185
00186   delete[] mim_bndy_;
00187   mim_bndy_ = nullptr;
00188
00189   delete[] divergence_;
00190   divergence_ = nullptr;
00191 }
00192
00193 bool mtk::Div1D::ConstructDiv1D(int order_accuracy,
00194                                 mtk::Real mimetic_threshold) {
00195
00196   #ifdef MTK_PERFORM_PREVENTIONS
00197   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00198   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00199   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00200                       __FILE__, __LINE__, __func__);
00201
00202   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00203     std::cout << "WARNING: Numerical accuracy is critical." << std::endl;
00204   }
00205
00206   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00207   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00208   #endif
00209
00210   order_accuracy_ = order_accuracy;
00211   mimetic_threshold_ = mimetic_threshold;
00212
00214
00215   bool abort_construction = ComputeStencilInteriorGrid();
00216
00217   #ifdef MTK_PERFORM_PREVENTIONS
00218   if (!abort_construction) {
00219     std::cerr << "Could NOT complete stage 1." << std::endl;
00220     std::cerr << "Exiting..." << std::endl;
00221     return false;
00222   }
00223   #endif
00224
00225   // At this point, we already have the values for the interior stencil stored
00226   // in the coeffs_interior_ array.
00227
00228   // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00229   // approximation at the boundary, thus it has no weights. For this case, the
00230   // dimension of the null-space of the Vandermonde matrices used to compute the
00231   // approximating coefficients at the boundary is 0. Ergo, we compute this
00232   // number first and then decide if we must compute anything at the boundary.
00233
00234   dim_null_ = order_accuracy_/2 - 1;
00235
00236   if (dim_null_ > 0) {
00237
00238     #ifdef MTK_PRECISION_DOUBLE
00239     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00240     #else
00241     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00242     #endif
00243
00245
00246     // For this we will follow recommendations given in:
00247     //
00248     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00249     //
00250     // We will compute the QR Factorization of the transpose, as in the
00251     // following (MATLAB) pseudo-code:
00252     //
00253     // [Q,R] = qr(V'); % Full QR as defined in
00254     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00255     //
00256     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00257     //
00258     // However, given the nature of the Vandermonde matrices we've just
```

```
00259     // computed, they all posses the same null-space. Therefore, we impose the
00260     // convention of computing the null-space of the first Vandermonde matrix
00261     // (west boundary).
00262
00263     abort_construction = ComputeRationalBasisNullSpace();
00264
00265     #ifdef MTK_PERFORM_PREVENTIONS
00266     if (!abort_construction) {
00267       std::cerr << "Could NOT complete stage 2.1." << std::endl;
00268       std::cerr << "Exiting..." << std::endl;
00269       return false;
00270     }
00271     #endif
00272
00274
00275     abort_construction = ComputePreliminaryApproximations();
00276
00277     #ifdef MTK_PERFORM_PREVENTIONS
00278     if (!abort_construction) {
00279       std::cerr << "Could NOT complete stage 2.2." << std::endl;
00280       std::cerr << "Exiting..." << std::endl;
00281       return false;
00282     }
00283     #endif
00284
00286
00287     abort_construction = ComputeWeights();
00288
00289     #ifdef MTK_PERFORM_PREVENTIONS
00290     if (!abort_construction) {
00291       std::cerr << "Could NOT complete stage 2.3." << std::endl;
00292       std::cerr << "Exiting..." << std::endl;
00293       return false;
00294     }
00295     #endif
00296
00298
00299     abort_construction = ComputeStencilBoundaryGrid();
00300
00301     #ifdef MTK_PERFORM_PREVENTIONS
00302     if (!abort_construction) {
00303       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00304       std::cerr << "Exiting..." << std::endl;
00305       return false;
00306     }
00307     #endif
00308
00309   } // End of: if (dim_null_ > 0);
00310
00312
00313   // Once we have the following three collections of data:
00314   //   (a) the coefficients for the interior,
00315   //   (b) the coefficients for the boundary (if it applies),
00316   //   (c) and the weights (if it applies),
00317   // we will store everything in the output array:
00318
00319   abort_construction = AssembleOperator();
00320
00321   #ifdef MTK_PERFORM_PREVENTIONS
00322   if (!abort_construction) {
00323     std::cerr << "Could NOT complete stage 3." << std::endl;
00324     std::cerr << "Exiting..." << std::endl;
00325     return false;
00326   }
00327   #endif
00328
00329   return true;
00330 }
00331
00332 int mtk::Div1D::num_bndy_coeffs() const {
00333
00334   return num_bndy_coeffs_;
00335 }
00336
00337 mtk::Real *mtk::Div1D::coeffs_interior() const {
00338
00339   return coeffs_interior_;
00340 }
00341
00342 mtk::Real *mtk::Div1D::weights_crs() const {
00343
```

```
00344   return weights_crs_;
00345 }
00346
00347 mtk::Real *mtk::Div1D::weights_cbs() const {
00348
00349   return weights_cbs_;
00350 }
00351
00352 int mtk::Div1D::num_feasible_sols() const {
00353
00354   return num_feasible_sols_;
00355 }
00356
00357 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00358
00359   mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00360
00361   auto counter = 0;
00362   for (auto ii = 0; ii < dim_null_; ++ii) {
00363     for(auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00364       xx.SetValue(ii,jj, divergence_[2*order_accuracy_ + 1 + counter]);
00365       counter++;
00366     }
00367   }
00368
00369   return xx;
00370 }
00371
00372 std::vector<mtk::Real> mtk::Div1D::sums_rows_mim_bndy() const {
00373
00374   return sums_rows_mim_bndy_;
00375 }
00376
00377 mtk::Real mtk::Div1D::mimetic_measure() const {
00378
00379   return mimetic_measure_;
00380 }
00381
00382 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(
00383   const UniStgGrid1D &grid) const {
00384
00385   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00386
00387   #ifdef MTK_PERFORM_PREVENTIONS
00388   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00389   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00390   #endif
00391
00392   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00393
00394   int dd_num_rows = nn + 2;
00395   int dd_num_cols = nn + 1;
00396   int elements_per_row = num_bndy_coeffs_;
00397   int num_extra_rows = dim_null_;
00398
00399   // Output matrix featuring sizes for divergence operators.
00400   mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00401
00403
00404   auto ee_index = 0;
00405   for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00406     auto cc = 0;
00407     for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00408       if( cc >= elements_per_row) {
00409         out.SetValue(ii, jj, mtk::kZero);
00410       } else {
00411         out.SetValue(ii,jj, mim_bndy_[ee_index++]*inv_delta_x);
00412         cc++;
00413       }
00414     }
00415   }
00416
00418
00419   for (auto ii = num_extra_rows + 1;
00420        ii < dd_num_rows - num_extra_rows - 1; ii++) {
00421     auto jj = ii - num_extra_rows - 1;
00422     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00423       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00424     }
00425   }
00426
```

```
00428
00429   ee_index = 0;
00430   for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--)
00431 {
00432     auto cc = 0;
00433     for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00434       if( cc >= elements_per_row) {
00435         out.SetValue(ii,jj,0.0);
00436       } else {
00437         out.SetValue(ii,jj,-mim_bndy_[ee_index++]*inv_delta_x);
00438         cc++;
00439       }
00440      }
00441   }
00442
00443   return out;
00444 }
00445
00446 mtk::DenseMatrix mtk::Div1D::ReturnAsDimensionlessDenseMatrix
     (
00447   int num_cells_x) const {
00448
00449   int nn{num_cells_x}; // Number of cells on the grid.
00450
00451   #ifdef MTK_PERFORM_PREVENTIONS
00452   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00453   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00454   #endif
00455
00456   int dd_num_rows = nn + 2;
00457   int dd_num_cols = nn + 1;
00458   int elements_per_row = num_bndy_coeffs_;
00459   int num_extra_rows = dim_null_;
00460
00461   // Output matrix featuring sizes for gradient operators.
00462   mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00463
00465
00466   auto ee_index = 0;
00467   for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00468     auto cc = 0;
00469     for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00470       if( cc >= elements_per_row) {
00471         out.SetValue(ii, jj, mtk::kZero);
00472       } else {
00473         out.SetValue(ii,jj, mim_bndy_[ee_index++]);
00474         cc++;
00475       }
00476     }
00477   }
00478
00480
00481   for (auto ii = num_extra_rows + 1;
00482        ii < dd_num_rows - num_extra_rows - 1; ii++) {
00483     auto jj = ii - num_extra_rows - 1;
00484     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00485       out.SetValue(ii, jj, coeffs_interior_[cc]);
00486     }
00487   }
00488
00490
00491   ee_index = 0;
00492   for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--)
00493   {
00494     auto cc = 0;
00495     for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00496       if( cc >= elements_per_row) {
00497         out.SetValue(ii,jj,0.0);
00498       } else {
00499         out.SetValue(ii,jj,-mim_bndy_[ee_index++]);
00500         cc++;
00501       }
00502      }
00503   }
00504
00505   return out;
00506 }
00507
00508 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00509
00511
```

```
00512   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00513
00514   try {
00515     pp = new mtk::Real[order_accuracy_];
00516   } catch (std::bad_alloc &memory_allocation_exception) {
00517     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00518       std::endl;
00519     std::cerr << memory_allocation_exception.what() << std::endl;
00520   }
00521   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00522
00523   #ifdef MTK_PRECISION_DOUBLE
00524   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00525   #else
00526   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00527   #endif
00528
00529   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00530     pp[ii] = pp[ii - 1] + mtk::kOne;
00531   }
00532
00533   #if MTK_VERBOSE_LEVEL > 3
00534   std::cout << "pp =" << std::endl;
00535   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00536     std::cout << std::setw(12) << pp[ii];
00537   }
00538   std::cout << std::endl << std::endl;
00539   #endif
00540
00542
00543   bool transpose{false};
00544
00545   mtk::DenseMatrix vander_matrix(pp,
00546                                  order_accuracy_,
00547                                  order_accuracy_,
00548                                  transpose);
00549
00550   #if MTK_VERBOSE_LEVEL > 4
00551   std::cout << "vander_matrix = " << std::endl;
00552   std::cout << vander_matrix << std::endl;
00553   #endif
00554
00556
00557   try {
00558     coeffs_interior_ = new mtk::Real[order_accuracy_];
00559   } catch (std::bad_alloc &memory_allocation_exception) {
00560     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00561       std::endl;
00562     std::cerr << memory_allocation_exception.what() << std::endl;
00563   }
00564   memset(coeffs_interior_,
00565          mtk::kZero,
00566          sizeof(coeffs_interior_[0])*order_accuracy_);
00567
00568   coeffs_interior_[1] = mtk::kOne;
00569
00570   #if MTK_VERBOSE_LEVEL > 3
00571   std::cout << "oo =" << std::endl;
00572   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00573     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00574   }
00575   std::cout << std::endl;
00576   #endif
00577
00579
00580   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00581                                                 coeffs_interior_)};
00582
00583   #ifdef MTK_PERFORM_PREVENTIONS
00584   if (!info) {
00585     std::cout << "System solved! Interior stencil attained!" << std::endl;
00586     std::cout << std::endl;
00587   }
00588   else {
00589     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00590     std::cerr << "Exiting..." << std::endl;
00591     return false;
00592   }
00593   #endif
00594
00595   #if MTK_VERBOSE_LEVEL > 3
```

```
00596   std::cout << "coeffs_interior_ =" << std::endl;
00597   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00598     std::cout << std::setw(12) << coeffs_interior_[ii];
00599   }
00600   std::cout << std::endl << std::endl;
00601   #endif
00602
00603   delete [] pp;
00604   pp = nullptr;
00605
00606   return true;
00607 }
00608
00609 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00610
00611   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00612
00614
00615   try {
00616     gg = new mtk::Real[num_bndy_coeffs_];
00617   } catch (std::bad_alloc &memory_allocation_exception) {
00618     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00619       std::endl;
00620     std::cerr << memory_allocation_exception.what() << std::endl;
00621   }
00622   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00623
00624   #ifdef MTK_PRECISION_DOUBLE
00625   gg[0] = -1.0/2.0;
00626   #else
00627   gg[0] = -1.0f/2.0f;
00628   #endif
00629   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00630     gg[ii] = gg[ii - 1] + mtk::kOne;
00631   }
00632
00633   #if MTK_VERBOSE_LEVEL > 3
00634   std::cout << "gg =" << std::endl;
00635   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00636     std::cout << std::setw(12) << gg[ii];
00637   }
00638   std::cout << std::endl << std::endl;
00639   #endif
00640
00642
00643   bool tran{true}; // Should I transpose the Vandermonde matrix.
00644
00645   mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00646
00647   #if MTK_VERBOSE_LEVEL > 4
00648   std::cout << "vv_west_t =" << std::endl;
00649   std::cout << vv_west_t << std::endl;
00650   #endif
00651
00653
00654   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
     (vv_west_t));
00655
00656   #if MTK_VERBOSE_LEVEL > 4
00657   std::cout << "QQ^T = " << std::endl;
00658   std::cout << qq_t << std::endl;
00659   #endif
00660
00662
00663   int KK_num_rows_{num_bndy_coeffs_};
00664   int KK_num_cols_{dim_null_};
00665
00666   mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00667
00668   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00669     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00670       KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00671           qq_t.data()[ii*num_bndy_coeffs_ + jj];
00672     }
00673   }
00674
00675   #if MTK_VERBOSE_LEVEL > 2
00676   std::cout << "KK =" << std::endl;
00677   std::cout << KK << std::endl;
00678   std::cout << "KK.num_rows() = " << KK.num_rows() << std::endl;
00679   std::cout << "KK.num_cols() = " << KK.num_cols() << std::endl;
```

```
00680   std::cout << std::endl;
00681   #endif
00682
00684
00685   // Scale thus requesting that the last entries of the attained basis for the
00686   // null-space, adopt the pattern we require.
00687   // Essentially we will implement the following MATLAB pseudo-code:
00688   //  scalers = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00689   //  SK = KK*scalers
00690   // where SK is the scaled null-space.
00691
00692   // In this point, we almost have all the data we need correctly allocated
00693   // in memory. We will create the matrix II_, and elements we wish to scale in
00694   // the KK array. Using the concept of the leading dimension, we could just
00695   // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00696   // GET how does it work. So I will just create a matrix with the content of
00697   // this array that we need, solve for the scalers and then scale the
00698   // whole KK:
00699
00700   // We will then create memory for that sub-matrix of KK (SUBK).
00701
00702   mtk::DenseMatrix SUBK(dim_null_,dim_null_);
00703
00704   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00705     for (auto jj = 0; jj < dim_null_; ++jj) {
00706       SUBK.data()[(ii - (num_bndy_coeffs_ - dim_null_))*dim_null_ + jj] =
00707           KK.data()[ii*dim_null_ + jj];
00708     }
00709   }
00710
00711   #if MTK_VERBOSE_LEVEL > 4
00712   std::cout << "SUBK =" << std::endl;
00713   std::cout << SUBK << std::endl;
00714   #endif
00715
00716   SUBK.Transpose();
00717
00718   #if MTK_VERBOSE_LEVEL > 4
00719   std::cout << "SUBK^T =" << std::endl;
00720   std::cout << SUBK << std::endl;
00721   #endif
00722
00723   bool padded{false};
00724   tran = false;
00725
00726   mtk::DenseMatrix II(dim_null_, padded, tran);
00727
00728   #if MTK_VERBOSE_LEVEL > 4
00729   std::cout << "II =" << std::endl;
00730   std::cout << II << std::endl;
00731   #endif
00732
00733   // Solve the system to compute the scalers.
00734   // An example of the system to solve, for k = 8, is:
00735   //
00736   // SUBK*scalers = II_ or
00737   //
00738   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00739   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00740   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00741   //
00742   // Notice this is a nrhs = 3 system.
00743   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00744   // will be stored in the created identity matrix.
00745   // Let us first transpose SUBK (because of LAPACK):
00746
00747   int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00748
00749   #ifdef MTK_PERFORM_PREVENTIONS
00750   if (!info) {
00751     std::cout << "System successfully solved!" <<
00752       std::endl;
00753   } else {
00754     std::cerr << "Something went wrong solving system! info = " << info <<
00755       std::endl;
00756     std::cerr << "Exiting..." << std::endl;
00757     return false;
00758   }
00759   std::cout << std::endl;
00760   #endif
00761
```

```
00762   #if MTK_VERBOSE_LEVEL > 4
00763   std::cout << "Computed scalers:" << std::endl;
00764   std::cout << II << std::endl;
00765   #endif
00766
00767   // Multiply the two matrices to attain a scaled basis for null-space.
00768
00769   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00770
00771   #if MTK_VERBOSE_LEVEL > 4
00772   std::cout << "Rational basis for the null-space:" << std::endl;
00773   std::cout << rat_basis_null_space_ << std::endl;
00774   #endif
00775
00776   // At this point, we have a rational basis for the null-space, with the
00777   // pattern we need! :)
00778
00779   delete [] gg;
00780   gg = nullptr;
00781
00782   return true;
00783 }
00784
00785 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00786
00788
00789   mtk::Real *gg{}; // Generator vector for the first approximation.
00790
00791   try {
00792     gg = new mtk::Real[num_bndy_coeffs_];
00793   } catch (std::bad_alloc &memory_allocation_exception) {
00794     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00795 std::endl;
00796     std::cerr << memory_allocation_exception.what() << std::endl;
00797   }
00798   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00799
00800   #ifdef MTK_PRECISION_DOUBLE
00801   gg[0] = -1.0/2.0;
00802   #else
00803   gg[0] = -1.0f/2.0f;
00804   #endif
00805   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00806     gg[ii] = gg[ii - 1] + mtk::kOne;
00807   }
00808
00809   #if MTK_VERBOSE_LEVEL > 3
00810   std::cout << "gg0 =" << std::endl;
00811   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00812     std::cout << std::setw(12) << gg[ii];
00813   }
00814   std::cout << std::endl << std::endl;
00815   #endif
00816
00817   // Allocate 2D array to store the collection of preliminary approximations.
00818   try {
00819     prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
00820   } catch (std::bad_alloc &memory_allocation_exception) {
00821     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00822       std::endl;
00823     std::cerr << memory_allocation_exception.what() << std::endl;
00824   }
00825   memset(prem_apps_,
00826          mtk::kZero,
00827          sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00828
00830
00831   for (auto ll = 0; ll < dim_null_; ++ll) {
00832
00833     // Re-check new generator vector for every iteration except for the first.
00834     #if MTK_VERBOSE_LEVEL > 3
00835     if (ll > 0) {
00836       std::cout << "gg" << ll << " =" << std::endl;
00837       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00838         std::cout << std::setw(12) << gg[ii];
00839       }
00840       std::cout << std::endl << std::endl;
00841     }
00842     #endif
00843
00845
```

```
00846     bool transpose{false};
00847
00848     mtk::DenseMatrix AA_(gg,
00849                          num_bndy_coeffs_, order_accuracy_ + 1,
00850                          transpose);
00851
00852     #if MTK_VERBOSE_LEVEL > 4
00853     std::cout << "AA_" << ll << " =" << std::endl;
00854     std::cout << AA_ << std::endl;
00855     #endif
00856
00858
00859     mtk::Real *ob{};
00860
00861     auto ob_ld = num_bndy_coeffs_;
00862
00863     try {
00864       ob = new mtk::Real[ob_ld];
00865     } catch (std::bad_alloc &memory_allocation_exception) {
00866       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00867         std::endl;
00868       std::cerr << memory_allocation_exception.what() << std::endl;
00869     }
00870     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00871
00872     ob[1] = mtk::kOne;
00873
00874     #if MTK_VERBOSE_LEVEL > 4
00875     std::cout << "ob = " << std::endl << std::endl;
00876     for (auto ii = 0; ii < ob_ld; ++ii) {
00877       std::cout << std::setw(12) << ob[ii] << std::endl;
00878     }
00879     std::cout << std::endl;
00880     #endif
00881
00883
00884     // However, this is an under-determined system of equations. So we can not
00885     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00886     // our LAPACKAdapter class.
00887
00888     int info_{
00889       mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
      ob, ob_ld)};
00890
00891     #ifdef MTK_PERFORM_PREVENTIONS
00892     if (!info_) {
00893       std::cout << "System successfully solved!" << std::endl << std::endl;
00894     } else {
00895       std::cerr << "Error solving system! info = " << info_ << std::endl;
00896     }
00897     #endif
00898
00899     #if MTK_VERBOSE_LEVEL > 3
00900     std::cout << "ob =" << std::endl;
00901     for (auto ii = 0; ii < ob_ld; ++ii) {
00902       std::cout << std::setw(12) << ob[ii] << std::endl;
00903     }
00904     std::cout << std::endl;
00905     #endif
00906
00908
00909     // This implies a DAXPY operation. However, we must construct the arguments
00910     // for this operation.
00911
00913     // Save them into the ob_bottom array:
00914
00915     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00916
00917     try {
00918       ob_bottom = new mtk::Real[dim_null_];
00919     } catch (std::bad_alloc &memory_allocation_exception) {
00920       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00921         std::endl;
00922       std::cerr << memory_allocation_exception.what() << std::endl;
00923     }
00924     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00925
00926     for (auto ii = 0; ii < dim_null_; ++ii) {
00927       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00928     }
00929
```

```
00930     #if MTK_VERBOSE_LEVEL > 3
00931     std::cout << "ob_bottom =" << std::endl;
00932     for (auto ii = 0; ii < dim_null_; ++ii) {
00933       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00934     }
00935     std::cout << std::endl;
00936     #endif
00937
00939
00940     // We must computed an scaled ob, sob, using the scaled null-space in
00941     // rat_basis_null_space_.
00942     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00943     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00944     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00945
00946     #if MTK_VERBOSE_LEVEL > 3
00947     std::cout << "Rational basis for the null-space:" << std::endl;
00948     std::cout << rat_basis_null_space_ << std::endl;
00949     #endif
00950
00951     mtk::Real alpha{-mtk::kOne};
00952     mtk::Real beta{mtk::kOne};
00953
00954     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00955                                   ob_bottom, beta, ob);
00956
00957     #if MTK_VERBOSE_LEVEL > 3
00958     std::cout << "scaled ob:" << std::endl;
00959     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00960       std::cout << std::setw(12) << ob[ii] << std::endl;
00961     }
00962     std::cout << std::endl;
00963     #endif
00964
00965     // We save the recently scaled solution, into an array containing these.
00966     // We can NOT start building the pi matrix, simply because I want that part
00967     // to be separated since its construction depends on the algorithm we want
00968     // to implement.
00969
00970     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00971       prem_apps_[ii*dim_null_ + ll] = ob[ii];
00972     }
00973
00974     // After the first iteration, simply shift the entries of the last
00975     // generator vector used:
00976     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00977       gg[ii]--;
00978     }
00979
00980     // Garbage collection for this loop:
00981     delete[] ob;
00982     ob = nullptr;
00983
00984     delete[] ob_bottom;
00985     ob_bottom = nullptr;
00986   } // End of: for (ll = 0; ll < dim_null; ll++);
00987
00988   #if MTK_VERBOSE_LEVEL > 4
00989   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00990   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00991     for (auto jj = 0; jj < dim_null_; ++jj) {
00992       std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00993     }
00994     std::cout << std::endl;
00995   }
00996   std::cout << std::endl;
00997   #endif
00998
00999   delete[] gg;
01000   gg = nullptr;
01001
01002   return true;
01003 }
01004
01005 bool mtk::Div1D::ComputeWeights(void) {
01006
01007   // Matrix to compute the weights as in the CRSA.
01008   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01009
01011
01012   // Assemble the pi matrix using:
```

```
01013   // 1. The collection of scaled preliminary approximations.
01014   // 2. The collection of coefficients approximating at the interior.
01015   // 3. The scaled basis for the null-space.
01016
01017   // 1.1. Process array of scaled preliminary approximations.
01018
01019   // These are queued in scaled_solutions. Each one of these, will be a column
01020   // of the pi matrix:
01021   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01022     for (auto jj = 0; jj < dim_null_; ++jj) {
01023       pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
01024         prem_apps_[ii*dim_null_ + jj];
01025     }
01026   }
01027
01028   // 1.2. Add columns from known stencil approximating at the interior.
01029
01030   // However, these must be padded by zeros, according to their position in the
01031   // final pi matrix:
01032   auto mm = 0;
01033   for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
01034     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01035       pi.data()[(ii + mm)*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
01036         coeffs_interior_[ii];
01037     }
01038     ++mm;
01039   }
01040
01041   rat_basis_null_space_.OrderColMajor();
01042
01043   #if MTK_VERBOSE_LEVEL > 4
01044   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01045   std::cout << rat_basis_null_space_ << std::endl;
01046   #endif
01047
01048   // 1.3. Add final set of columns: rational basis for null-space.
01049
01050   for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
01051        jj < num_bndy_coeffs_ - 1;
01052        ++jj) {
01053     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01054       auto og =
01055         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
01056       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
01057       pi.data()[de] = rat_basis_null_space_.data()[og];
01058     }
01059   }
01060
01061   #if MTK_VERBOSE_LEVEL > 3
01062   std::cout << "coeffs_interior_ =" << std::endl;
01063   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01064     std::cout << std::setw(12) << coeffs_interior_[ii];
01065   }
01066   std::cout << std::endl << std::endl;
01067   #endif
01068
01069   #if MTK_VERBOSE_LEVEL > 4
01070   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01071   std::cout << pi << std::endl;
01072   #endif
01073
01075
01076   // This imposes the mimetic condition.
01077
01078   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
01079
01080   try {
01081     hh = new mtk::Real[num_bndy_coeffs_];
01082   } catch (std::bad_alloc &memory_allocation_exception) {
01083     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01084       std::endl;
01085     std::cerr << memory_allocation_exception.what() << std::endl;
01086   }
01087   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01088
01089   hh[0] = -mtk::kOne;
01090   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01091     auto aux_xx = mtk::kZero;
01092     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01093       aux_xx += coeffs_interior_[jj];
01094     }
```

```
01095     hh[ii] = -mtk::kOne*aux_xx;
01096   }
01097
01099
01100   // That is, we construct a system, to solve for the weights.
01101
01102   // Once again we face the challenge of solving with LAPACK. However, for the
01103   // CRSA, this matrix PI is over-determined, since it has more rows than
01104   // unknowns. However, according to the theory, the solution to this system is
01105   // unique. We will use dgels_.
01106
01107   try {
01108     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01109   } catch (std::bad_alloc &memory_allocation_exception) {
01110     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01111       std::endl;
01112     std::cerr << memory_allocation_exception.what() << std::endl;
01113   }
01114   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01115
01116   int weights_ld{pi.num_cols() + 1};
01117
01118   // Preserve hh.
01119   std::copy(hh, hh + weights_ld, weights_cbs_);
01120
01121   pi.Transpose();
01122
01123   int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
      pi,
01124                                                            weights_cbs_,
01125                                                            weights_ld)};
01126
01127   #ifdef MTK_PERFORM_PREVENTIONS
01128   if (!info) {
01129     std::cout << "System successfully solved!" << std::endl << std::endl;
01130   } else {
01131     std::cerr << "Error solving system! info = " << info << std::endl;
01132   }
01133   #endif
01134
01135   #if MTK_VERBOSE_LEVEL > 3
01136   std::cout << "hh =" << std::endl;
01137   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01138     std::cout << std::setw(11) << hh[ii] << std::endl;
01139   }
01140   std::cout << std::endl;
01141   #endif
01142
01143   // Preserve the original weights for research.
01144
01145   try {
01146     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01147   } catch (std::bad_alloc &memory_allocation_exception) {
01148     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01149       std::endl;
01150     std::cerr << memory_allocation_exception.what() << std::endl;
01151   }
01152   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01153
01154   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01155
01156   #if MTK_VERBOSE_LEVEL > 3
01157   std::cout << "weights_CRSA + lambda =" << std::endl;
01158   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01159     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01160   }
01161   std::cout << std::endl;
01162   #endif
01163
01165
01166   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01167
01169
01170     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01171
01172     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01173       for (auto jj = 0; jj < dim_null_; ++jj) {
01174         phi.data()[ii*(order_accuracy_) + jj] = prem_apps_[ii*dim_null_ + jj];
01175       }
01176     }
01177
```

```
01178     int aux{};  // Auxiliary variable.
01179     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01180       for (auto ii = 0; ii < order_accuracy_; ++ii) {
01181         phi.data()[(ii + aux)*order_accuracy_ + jj] = coeffs_interior_[ii];
01182       }
01183       ++aux;
01184     }
01185
01186     for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01187       for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01188         phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01189       }
01190     }
01191
01192     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01193       for (auto ii = 0; ii < dim_null_; ++ii) {
01194         phi.data()[(ii + order_accuracy_ - dim_null_ + jj*order_accuracy_)] =
01195           -prem_apps_[(dim_null_ - ii - 1 + jj*dim_null_)];
01196       }
01197     }
01198
01199     for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
01200       for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01201         auto swap = phi.data()[ii*order_accuracy_+jj];
01202         phi.data()[ii*order_accuracy_ + jj] =
01203           phi.data()[(order_accuracy_-ii)*order_accuracy_+jj];
01204         phi.data()[(order_accuracy_-ii)*order_accuracy_+jj] = swap;
01205       }
01206     }
01207
01208     #if MTK_VERBOSE_LEVEL > 4
01209     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01210     std::cout << phi << std::endl;
01211     #endif
01212
01214
01215     mtk::Real *lamed{};  // Used to build big lambda.
01216
01217     try {
01218       lamed = new mtk::Real[dim_null_];
01219     } catch (std::bad_alloc &memory_allocation_exception) {
01220       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01221         std::endl;
01222       std::cerr << memory_allocation_exception.what() << std::endl;
01223     }
01224     memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01225
01226     for (auto ii = 0; ii < dim_null_; ++ii) {
01227       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01228     }
01229
01230     #if MTK_VERBOSE_LEVEL > 3
01231     std::cout << "lamed =" << std::endl;
01232     for (auto ii = 0; ii < dim_null_; ++ii) {
01233       std::cout << std::setw(12) << lamed[ii] << std::endl;
01234     }
01235     std::cout << std::endl;
01236     #endif
01237
01238     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01239       mtk::Real temp = mtk::kZero;
01240       for(auto jj = 0; jj < dim_null_; ++jj) {
01241         temp = temp +
01242           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01243       }
01244       hh[ii] = hh[ii] - temp;
01245     }
01246
01247     #if MTK_VERBOSE_LEVEL > 3
01248     std::cout << "big_lambda =" << std::endl;
01249     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01250       std::cout << std::setw(12) << hh[ii] << std::endl;
01251     }
01252     std::cout << std::endl;
01253     #endif
01254
01255     #ifdef MTK_VERBOSE_WEIGHTS
01256     int copy_result{1};
01257     #else
01258     int copy_result{};
01259     #endif
```

```
01260
01261     mtk::Real normerr_; // Norm of the error for the solution on each row.
01262
01264
01265     int minrow_{std::numeric_limits<int>::infinity()};
01266
01267     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_crs_,
      order_accuracy_)};
01268     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01269
01270     #ifdef MTK_VERBOSE_WEIGHTS
01271     std::ofstream table("div_1d_" + std::to_string(order_accuracy_) +
01272       "_weights.tex");
01273
01274     table << "\\begin{tabular}[c]{c";
01275     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01276       table << 'c';
01277     }
01278     table << ":c}\n\\toprule\nRow & ";
01279     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01280       table << "$ q_{" + std::to_string(ii) + "}$ &";
01281     }
01282     table << " Relative error \\\\\n\\midrule\n";
01283     #endif
01284
01285     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01286       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01287                                                           order_accuracy_ + 1,
01288                                                           order_accuracy_,
01289                                                           order_accuracy_,
01290                                                           hh,
01291                                                           weights_cbs_,
01292                                                           row_,
01293                                                           mimetic_threshold_,
01294                                                           copy_result);
01295       mtk::Real aux{normerr_/norm_};
01296
01297       #if MTK_VERBOSE_LEVEL > 2
01298       std::cout << "Relative norm: " << aux << " " << std::endl;
01299       std::cout << std::endl;
01300       #endif
01301
01302       num_feasible_sols_ = num_feasible_sols_ +
01303         (int) (normerr_ != std::numeric_limits<mtk::Real>::infinity());
01304
01305       if (aux < minnorm_) {
01306         minnorm_ = aux;
01307         minrow_= row_;
01308       }
01309
01310       #ifdef MTK_VERBOSE_WEIGHTS
01311       table << std::to_string(row_ + 1) << " & ";
01312       if (normerr_ != std::numeric_limits<mtk::Real>::infinity()) {
01313         for (int ii = 1; ii <= order_accuracy_; ++ii) {
01314           table << std::to_string(weights_cbs_[ii - 1]) + " & ";
01315         }
01316         table << std::to_string(aux) << " \\\\" << std::endl;
01317       } else {
01318         table << "\\multicolumn{" << std::to_string(order_accuracy_) <<
01319           "}{c}{$\\emptyset$} & ";
01320         table << " - \\\\" << std::endl;
01321       }
01322       #endif
01323     }
01324
01325     #ifdef MTK_VERBOSE_WEIGHTS
01326     table << "\\midrule" << std::endl;
01327     table << "CRS weights:";
01328     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01329       table << " & " << std::to_string(weights_crs_[ii - 1]);
01330     }
01331     table << " & - \\\\\n\\bottomrule\n\\end{tabular}" << std::endl;
01332     table.close();
01333     #endif
01334
01335     #if MTK_VERBOSE_LEVEL > 3
01336     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01337       std::endl;
01338     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01339       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
```

```
01340     }
01341     std::cout << std::endl;
01342     #endif
01343
01345
01346     // After we know which row yields the smallest relative norm that row is
01347     // chosen to be the objective function and the result of the optimizer is
01348     // chosen to be the new weights_.
01349
01350     #if MTK_VERBOSE_LEVEL > 2
01351     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01352       minrow_ + 1 << std::endl;
01353     std::cout << std::endl;
01354     #endif
01355
01356     copy_result = 1;
01357     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01358                                                         order_accuracy_ + 1,
01359                                                         order_accuracy_,
01360                                                         order_accuracy_,
01361                                                         hh,
01362                                                         weights_cbs_,
01363                                                         minrow_,
01364                                                         mimetic_threshold_,
01365                                                         copy_result);
01366     mtk::Real aux_{normerr_/norm_};
01367     #if MTK_VERBOSE_LEVEL > 2
01368     std::cout << "Relative norm: " << aux_ << std::endl;
01369     std::cout << std::endl;
01370     #endif
01371
01372     delete [] lamed;
01373     lamed = nullptr;
01374   }
01375
01376   delete [] hh;
01377   hh = nullptr;
01378
01379   return true;
01380 }
01381
01382 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01383
01384   #if MTK_VERBOSE_LEVEL > 3
01385   std::cout << "weights_CBSA + lambda =" << std::endl;
01386   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01387     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01388   }
01389   std::cout << std::endl;
01390   #endif
01391
01393
01394   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01395
01396   try {
01397     lambda = new mtk::Real[dim_null_];
01398   } catch (std::bad_alloc &memory_allocation_exception) {
01399     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01400       std::endl;
01401     std::cerr << memory_allocation_exception.what() << std::endl;
01402   }
01403   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01404
01405   for (auto ii = 0; ii < dim_null_; ++ii) {
01406     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01407   }
01408
01409   #if MTK_VERBOSE_LEVEL > 3
01410   std::cout << "lambda =" << std::endl;
01411   for (auto ii = 0; ii < dim_null_; ++ii) {
01412     std::cout << std::setw(12) << lambda[ii] << std::endl;
01413   }
01414   std::cout << std::endl;
01415   #endif
01416
01418
01419   mtk::Real *alpha{}; // Collection of alpha values.
01420
01421   try {
01422     alpha = new mtk::Real[dim_null_];
```

```
01423   } catch (std::bad_alloc &memory_allocation_exception) {
01424     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01425       std::endl;
01426     std::cerr << memory_allocation_exception.what() << std::endl;
01427   }
01428   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01429
01430   for (auto ii = 0; ii < dim_null_; ++ii) {
01431     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01432   }
01433
01434   #if MTK_VERBOSE_LEVEL > 3
01435   std::cout << "alpha =" << std::endl;
01436   for (auto ii = 0; ii < dim_null_; ++ii) {
01437     std::cout << std::setw(12) << alpha[ii] << std::endl;
01438   }
01439   std::cout << std::endl;
01440   #endif
01441
01443
01444   try {
01445     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01446   } catch (std::bad_alloc &memory_allocation_exception) {
01447     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01448       std::endl;
01449     std::cerr << memory_allocation_exception.what() << std::endl;
01450   }
01451   memset(mim_bndy_,
01452          mtk::kZero,
01453          sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01454
01455   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01456     for (auto jj = 0; jj < dim_null_; ++jj) {
01457       mim_bndy_[ii*dim_null_ + jj] =
01458         prem_apps_[ii*dim_null_ + jj] +
01459         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01460     }
01461   }
01462
01463   #if MTK_VERBOSE_LEVEL > 3
01464   std::cout << "Collection of mimetic approximations:" << std::endl;
01465   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01466     for (auto jj = 0; jj < dim_null_; ++jj) {
01467       std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01468     }
01469     std::cout << std::endl;
01470   }
01471   std::cout << std::endl;
01472   #endif
01473
01475
01476   for (auto ii = 0; ii < dim_null_; ++ii) {
01477     sums_rows_mim_bndy_.push_back(mtk::kZero);
01478     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01479       sums_rows_mim_bndy_[ii] += mim_bndy_[jj*dim_null_ + ii];
01480     }
01481   }
01482
01483     mimetic_measure_ = *std::max_element(sums_rows_mim_bndy_.begin(),
01484                                          sums_rows_mim_bndy_.end());
01485
01486   #if MTK_VERBOSE_LEVEL > 3
01487   std::cout << "Row-wise sum of mimetic approximations:" << std::endl;
01488   for (auto ii = 0; ii < dim_null_; ++ii) {
01489     std::cout << std::setw(13) << sums_rows_mim_bndy_[ii];
01490   }
01491   std::cout << std::endl;
01492   std::cout << std::endl;
01493   #endif
01494
01495   delete[] lambda;
01496   lambda = nullptr;
01497
01498   delete[] alpha;
01499   alpha = nullptr;
01500
01501   return true;
01502 }
01503
01504 bool mtk::Div1D::AssembleOperator(void) {
01505
```

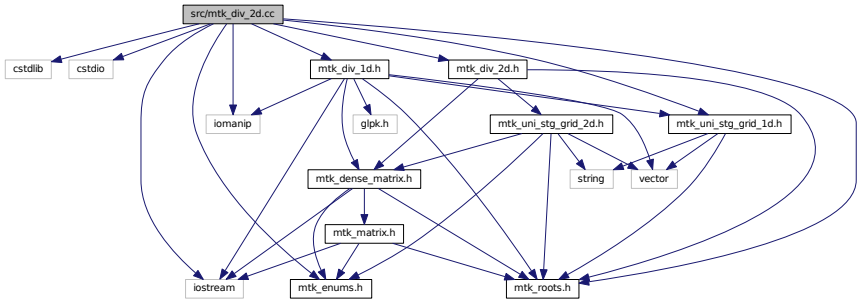
```
01506   // The output array will have this form:
01507   // 1. The first entry of the array will contain used order order_accuracy_.
01508   // 2. The second entry of the array will contain the collection of
01509   // approximating coefficients for the interior of the grid.
01510   // 3. IF order_accuracy_ > 2, then the third entry will contain a collection
01511   // of weights.
01512   // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the
01513   // collections of approximating coefficients for the west boundary of the
01514   // grid.
01515
01516   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01517     divergence_length_ =
01518       1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
01519   } else {
01520     divergence_length_ = 1 + order_accuracy_;
01521   }
01522
01523   #if MTK_VERBOSE_LEVEL > 2
01524   std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01525   std::cout << std::endl;
01526   #endif
01527
01528   try {
01529     divergence_ = new double[divergence_length_];
01530   } catch (std::bad_alloc &memory_allocation_exception) {
01531     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01532       std::endl;
01533     std::cerr << memory_allocation_exception.what() << std::endl;
01534   }
01535   memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01536
01538
01539   divergence_[0] = order_accuracy_;
01540
01542
01543   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01544   divergence_[ii + 1] = coeffs_interior_[ii];
01545   }
01546
01548
01549   if (order_accuracy_ > 2) {
01550     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01551       divergence_[(1 + order_accuracy_) + ii] = weights_cbs_[ii];
01552     }
01553   }
01554
01557
01558   if (order_accuracy_ > 2) {
01559     auto offset = (2*order_accuracy_ + 1);
01560     int mm{};
01561     for (auto ii = 0; ii < dim_null_; ++ii) {
01562       for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01563         divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01564         ++mm;
01565       }
01566     }
01567   }
01568
01569   #if MTK_VERBOSE_LEVEL > 1
01570   std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01571   std::cout << std::endl;
01572   #endif
01573
01574   return true;
01575 }
```

18.91 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:



18.91.1 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.

18.92 mtk_div_2d.cc

```
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
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00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

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00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_1d.h"
00066 #include "mtk_div_1d.h"
00067 #include "mtk_div_2d.h"
00068
00069 mtk::Div2D::Div2D():
00070   order_accuracy_(),
00071   mimetic_threshold_() {}
00072
00073 mtk::Div2D::Div2D(const Div2D &div):
00074   order_accuracy_(div.order_accuracy_),
00075   mimetic_threshold_(div.mimetic_threshold_) {}
00076
00077 mtk::Div2D::~Div2D() {}
00078
00079 bool mtk::Div2D::ConstructDiv2D(const
      mtk::UniStgGrid2D &grid,
00080                                 int order_accuracy,
00081                                 mtk::Real mimetic_threshold) {
00082
00083   int num_cells_x = grid.num_cells_x();
00084   int num_cells_y = grid.num_cells_y();
00085
00086   int mx = num_cells_x + 2;  // Dx vertical dimension.
00087   int nx = num_cells_x + 1;  // Dx horizontal dimension.
00088   int my = num_cells_y + 2;  // Dy vertical dimension.
00089   int ny = num_cells_y + 1;  // Dy horizontal dimension.
00090
00091   mtk::Div1D div;
00092
00093   bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00094
00095   #ifdef MTK_PERFORM_PREVENTIONS
00096   if (!info) {
00097     std::cerr << "Mimetic div could not be built." << std::endl;
00098     return info;
00099   }
00100   #endif
00101
00102   auto west = grid.west_bndy();
00103   auto east = grid.east_bndy();
00104   auto south = grid.south_bndy();
00105   auto north = grid.east_bndy();
00106
00107   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00108   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00109
00110   mtk::DenseMatrix dx(div.ReturnAsDenseMatrix(grid_x));
```

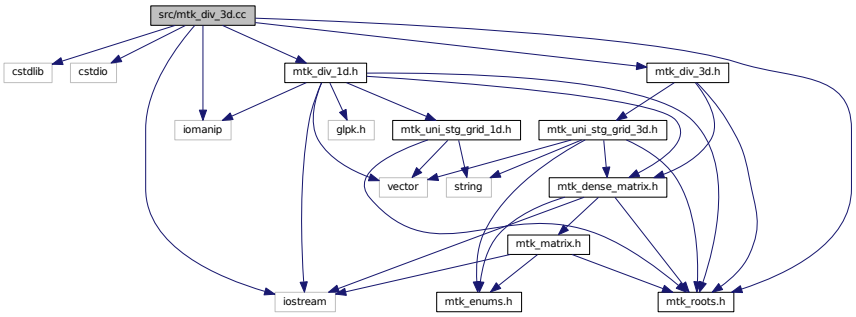
```
00111   mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00112
00113   bool padded{true};
00114   bool transpose{false};
00115
00116   mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00117   mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00118
00119   mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00120   mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00121
00122   #if MTK_VERBOSE_LEVEL > 2
00123   std::cout << "Dx: " << mx << " by " << nx << std::endl;
00124   std::cout << "Iy : " << num_cells_y<< " by " << ny  << std::endl;
00125   std::cout << "Dy: " << my << " by " << ny << std::endl;
00126   std::cout << "Ix : " << num_cells_x<< " by " << nx  << std::endl;
00127   std::cout << "Div 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00128     nx*ny <<std::endl;
00129   #endif
00130
00131   mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00132
00133   for (auto ii = 0; ii < mx*my; ii++) {
00134     for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00135       d2d.SetValue(ii, jj, dxy.GetValue(ii,jj));
00136     }
00137     for(auto kk = 0; kk<ny*num_cells_x; kk++) {
00138       d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00139     }
00140   }
00141
00142   divergence_ = d2d;
00143
00144   return info;
00145 }
00146
00147 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix() const {
00148
00149   return divergence_;
00150 }
```

18.93 src/mtk_div_3d.cc File Reference

Implements the class Div3D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_div_1d.h"
#include "mtk_div_3d.h"
```

Include dependency graph for mtk_div_3d.cc:



18.93.1 Detailed Description

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

Author

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

Definition in file mtk_div_3d.cc.

18.94 mtk_div_3d.cc

```
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00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
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```

```
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00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_div_1d.h"
00065 #include "mtk_div_3d.h"
00066
00067 mtk::Div3D::Div3D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Div3D::Div3D(const Div3D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Div3D::~Div3D() {}
00076
00077 bool mtk::Div3D::ConstructDiv3D(const
      mtk::UniStgGrid3D &grid,
00078                                 int order_accuracy,
00079                                 mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083   int num_cells_z = grid.num_cells_z();
00084
00085   int mx = num_cells_x + 1;  // Dx vertical dimension.
00086   int nx = num_cells_x + 2;  // Dx horizontal dimension.
00087   int my = num_cells_y + 1;  // Dy vertical dimension.
00088   int ny = num_cells_y + 2;  // Dy horizontal dimension.
00089   int mz = num_cells_z + 1;  // Dz vertical dimension.
00090   int nz = num_cells_z + 2;  // Dz horizontal dimension.
00091
00092   mtk::Div1D div;
00093
00094   bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00095
00096   #ifdef MTK_PERFORM_PREVENTIONS
00097   if (!info) {
00098     std::cerr << "Mimetic div could not be built." << std::endl;
00099     return info;
00100   }
00101   #endif
00102
00103   auto west = grid.west_bndy();
00104   auto east = grid.east_bndy();
00105   auto south = grid.south_bndy();
00106   auto north = grid.east_bndy();
00107   auto bottom = grid.bottom_bndy();
00108   auto top = grid.top_bndy();
00109
00110   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00111   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00112   mtk::UniStgGrid1D grid_z(bottom, top, num_cells_z);
00113
00114   mtk::DenseMatrix Dx(div.ReturnAsDenseMatrix(grid_x));
00115   mtk::DenseMatrix Dy(div.ReturnAsDenseMatrix(grid_y));
00116   mtk::DenseMatrix Dz(div.ReturnAsDenseMatrix(grid_z));
00117
00118   bool padded{true};
00119   bool transpose{false};
00120
00121   mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00122   mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00123   mtk::DenseMatrix iz(num_cells_z, padded, transpose);
```

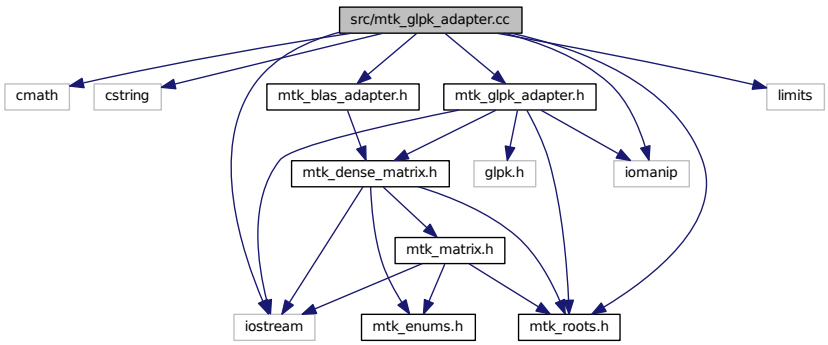
```
00124
00126
00127   mtk::DenseMatrix aux1(mtk::DenseMatrix::Kron(iz, iy));
00128   mtk::DenseMatrix dx(mtk::DenseMatrix::Kron(aux1, Dx));
00129
00131
00132   mtk::DenseMatrix aux2(mtk::DenseMatrix::Kron(iz, Dy));
00133   mtk::DenseMatrix dy(mtk::DenseMatrix::Kron(aux2, ix));
00134
00136
00137   mtk::DenseMatrix aux3(mtk::DenseMatrix::Kron(Dz, iy));
00138   mtk::DenseMatrix dz(mtk::DenseMatrix::Kron(aux3, ix));
00139
00140   #if MTK_VERBOSE_LEVEL > 2
00141   std::cout << "Dx: " << mx << " by " << nx << std::endl;
00142   std::cout << "Ix: " << num_cells_x << " by " << nx  << std::endl;
00143   std::cout << "Dy: " << my << " by " << ny << std::endl;
00144   std::cout << "Iy: " << num_cells_y << " by " << ny  << std::endl;
00145   std::cout << "Dz: " << mz << " by " << nz << std::endl;
00146   std::cout << "Iz: " << num_cells_z << " by " << nz  << std::endl;
00147   #endif
00148
00150
00151   int total_rows{nx*ny*nz};
00152   int total_cols{mx*num_cells_y*num_cells_z +
00153                  num_cells_x*my*num_cells_z +
00154                  num_cells_x*num_cells_y*mz};
00155
00156   #if MTK_VERBOSE_LEVEL > 2
00157   std::cout << "Div 3D: " << total_rows << " by " << total_cols << std::endl;
00158   #endif
00159
00160   mtk::DenseMatrix d3d(total_rows, total_cols);
00161
00162   for (auto ii = 0; ii < total_rows; ++ii) {
00163
00164     for (auto jj = 0; jj < mx*num_cells_y*num_cells_z; ++jj) {
00165       d3d.SetValue(ii, jj, dx.GetValue(ii, jj));
00166     }
00167
00168     int offset = mx*num_cells_y*num_cells_z;
00169
00170     for(auto kk = 0; kk < num_cells_x*my*num_cells_z; ++kk) {
00171       d3d.SetValue(ii, kk + offset, dy.GetValue(ii, kk));
00172     }
00173
00174     offset += num_cells_x*my*num_cells_z;
00175
00176     for(auto ll = 0; ll < num_cells_x*num_cells_y*mz; ++ll) {
00177       d3d.SetValue(ii, ll + offset, dz.GetValue(ii, ll));
00178     }
00179   }
00180
00181   divergence_ = d3d;
00182
00183   return info;
00184 }
00185
00186 mtk::DenseMatrix mtk::Div3D::ReturnAsDenseMatrix() const {
00187
00188   return divergence_;
00189 }
```

18.95 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:



18.95.1 Detailed Description

Implementation of a class that contains a collection of static member functions, 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.

18.96 mtk_glpk_adapter.cc

```
00001
00020 /*
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00022 University. All rights reserved.
00023
00024 Redistribution and use in source and binary forms, with or without modification,
```

```
00025 are permitted provided that the following conditions are met:
00026
00027 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00028 and a copy of the modified files should be reported once modifications are
00029 completed, unless these modifications are made through the project's GitHub
00030 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00031 should be developed and included in any deliverable.
00032
00033 2. Redistributions of source code must be done through direct
00034 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00035
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00039
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00061 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00062 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00063 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00064 */
00065
00066 #include <cmath>
00067 #include <cstring>
00068
00069 #include <iostream>
00070 #include <iomanip>
00071 #include <limits>
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_blas_adapter.h"
00075 #include "mtk_glpk_adapter.h"
00076
00077 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
      mtk::Real *A,
00078                                                    int nrows,
00079                                                    int ncols,
00080                                                    int kk,
00081                                                    mtk::Real *hh,
00082                                                    mtk::Real *qq,
00083                                                    int robjective,
00084                                                    mtk::Real mimetic_threshold,
00085                                                    int copy) noexcept {
00086
00087   #if MTK_DEBUG_LEVEL > 0
00088   char mps_file_name[18]; // File name for the MPS files.
00089   #endif
00090   char rname[5];          // Row name.
00091   char cname[5];          // Column name.
00092
00093   glp_prob *lp; // Linear programming problem.
00094
00095   int *ia;  // Array for the problem.
00096   int *ja;  // Array for the problem.
00097
00098   int problem_size; // Size of the problem.
00099   int lp_nrows;     // Number of rows.
00100   int lp_ncols;     // Number of columns.
00101   int matsize;      // Size of the matrix.
00102   int glp_index{1}; // Index of the objective function.
00103   int ii;           // Iterator.
00104   int jj;           // Iterator.
```

```
00105
00106   mtk::Real *ar;            // Array for the problem.
00107   mtk::Real *objective;     // Array containing the objective function.
00108   mtk::Real *rhs;           // Array containing the rhs.
00109   mtk::Real *err;           // Array of errors.
00110
00111   mtk::Real xl;             // Norm-2 of the error.
00112
00113   #if MTK_DEBUG_LEVEL > 0
00114   mtk::Real obj_value;      // Value of the objective function.
00115   #endif
00116
00117   lp_nrows = kk;
00118   lp_ncols = kk;
00119
00120   matsize = lp_nrows*lp_ncols;
00121
00123
00125
00126   problem_size = lp_nrows*lp_ncols + 1;
00127
00128   try {
00129     ia = new int[problem_size];
00130   } catch (std::bad_alloc &memory_allocation_exception) {
00131     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00132       std::endl;
00133     std::cerr << memory_allocation_exception.what() << std::endl;
00134   }
00135   memset(ia, 0, sizeof(ia[0])*problem_size);
00136
00137   try {
00138     ja = new int[problem_size];
00139   } catch (std::bad_alloc &memory_allocation_exception) {
00140     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00141       std::endl;
00142     std::cerr << memory_allocation_exception.what() << std::endl;
00143   }
00144   memset(ja, 0, sizeof(ja[0])*problem_size);
00145
00146   try {
00147     ar = new mtk::Real[problem_size];
00148   } catch (std::bad_alloc &memory_allocation_exception) {
00149     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00150       std::endl;
00151     std::cerr << memory_allocation_exception.what() << std::endl;
00152   }
00153   memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00154
00155   try {
00156     objective = new mtk::Real[lp_ncols + 1];
00157   } catch (std::bad_alloc &memory_allocation_exception) {
00158     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00159       std::endl;
00160     std::cerr << memory_allocation_exception.what() << std::endl;
00161   }
00162   memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00163
00164   try {
00165     rhs = new mtk::Real[lp_nrows + 1];
00166   } catch (std::bad_alloc &memory_allocation_exception) {
00167     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00168       std::endl;
00169     std::cerr << memory_allocation_exception.what() << std::endl;
00170   }
00171   memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00172
00173   try {
00174     err = new mtk::Real[lp_nrows];
00175   } catch (std::bad_alloc &memory_allocation_exception) {
00176     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00177       std::endl;
00178     std::cerr << memory_allocation_exception.what() << std::endl;
00179   }
00180   memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00181
00182   #if MTK_DEBUG_LEVEL > 0
00183   std::cout << "Problem size: " << problem_size << std::endl;
00184   std::cout << "lp_nrows = " << lp_nrows << std::endl;
00185   std::cout << "lp_ncols = " << lp_ncols << std::endl;
00186   std::cout << std::endl;
00187   #endif
```

```
00188
00189   lp = glp_create_prob();
00190
00191   glp_set_prob_name (lp, "mtk::GLPKAdapter::Simplex");
00192
00193   glp_set_obj_dir (lp, GLP_MIN);
00194
00196
00197   glp_add_rows(lp, lp_nrows);
00198
00199   for (ii = 1; ii <= lp_nrows; ++ii) {
00200     sprintf(rname, "R%02d",ii);
00201     glp_set_row_name(lp, ii, rname);
00202   }
00203
00204   glp_add_cols(lp, lp_ncols);
00205
00206   for (ii = 1; ii <= lp_ncols; ++ii) {
00207     sprintf(cname, "Q%02d",ii);
00208     glp_set_col_name (lp, ii, cname);
00209   }
00210
00212
00213   #if MTK_DEBUG_LEVEL>0
00214   std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00215   #endif
00216   for (jj = 0; jj < kk; ++jj) {
00217     objective[glp_index] = A[jj + robjective * ncols];
00218     glp_index++;
00219   }
00220   #if MTK_DEBUG_LEVEL >0
00221   std::cout << std::endl;
00222   #endif
00223
00225
00226   glp_index = 1;
00227   rhs[0] = mtk::kZero;
00228   for (ii = 0; ii <= lp_nrows; ++ii) {
00229     if (ii != robjective) {
00230       rhs[glp_index] = hh[ii];
00231       glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00232       glp_index++;
00233     }
00234   }
00235
00236   #if MTK_DEBUG_LEVEL > 0
00237   std::cout << "rhs =" << std::endl;
00238   for (auto ii = 0; ii < lp_nrows; ++ii) {
00239     std::cout << std::setw(15) << rhs[ii] << std::endl;
00240   }
00241   std::cout << std::endl;
00242   #endif
00243
00245
00246   for (ii = 1; ii <= lp_ncols; ++ii) {
00247     glp_set_obj_coef (lp, ii, objective[ii]);
00248   }
00249
00251
00252   for (ii = 1; ii <= lp_ncols; ++ii) {
00253     glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00254   }
00255
00257
00258   glp_index = 1;
00259   for (ii = 0; ii <= kk; ++ii) {
00260     for (jj = 0; jj < kk; ++jj) {
00261       if (ii != robjective) {
00262         ar[glp_index] = A[jj + ii * ncols];
00263         glp_index++;
00264       }
00265     }
00266   }
00267
00268   glp_index = 0;
00269
00270   for (ii = 1; ii < problem_size; ++ii) {
00271     if (((ii - 1) % lp_ncols) == 0) {
00272       glp_index++;
00273     }
00274     ia[ii] = glp_index;
```

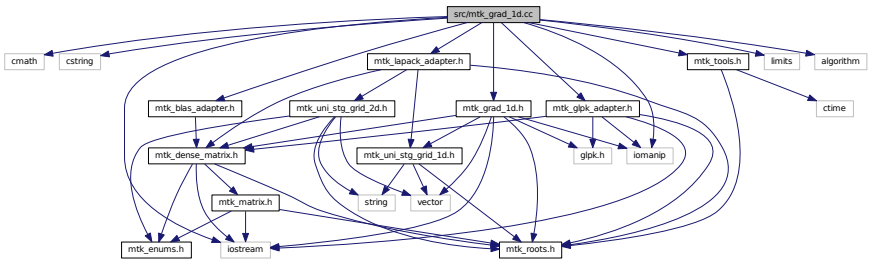
```
00275     ja[ii] = (ii - 1) % lp_ncols + 1;
00276   }
00277
00278   glp_load_matrix (lp, matsize, ia, ja, ar);
00279
00280   #if MTK_DEBUG_LEVEL > 0
00281   sprintf(mps_file_name, "LP_MPS_row_%02d.mps", robjective);
00282   glp_write_mps(lp, GLP_MPS_FILE, nullptr, mps_file_name);
00283   #endif
00284
00286
00287   glp_simplex (lp, nullptr);
00288
00289   // Check status of the solution, determining if this was a feasible solution.
00290
00291   if (glp_get_status(lp) == GLP_OPT) {
00292
00293     for(ii = 1; ii <= lp_ncols; ++ii) {
00294       err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp,ii);
00295     }
00296
00297     #if MTK_DEBUG_LEVEL > 0
00298     obj_value = glp_get_obj_val (lp);
00299     std::cout << std::setw(12) << "CBS" << std::setw(12) << "CRS" << std::endl;
00300     for (ii = 0; ii < lp_ncols; ++ii) {
00301       std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00302         glp_get_col_prim(lp,ii + 1) << std::setw(12) << qq[ii] << std::endl;
00303     }
00304     std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00305       obj_value << std::endl;
00306     #endif
00307
00308     if (copy) {
00309       for(ii = 0; ii < lp_ncols; ++ii) {
00310         qq[ii] = glp_get_col_prim(lp,ii + 1);
00311       }
00312       // Preserve the bottom values of qq.
00313     }
00314
00315     x1 = mtk::BLASAdapter::RealNRM2(err,lp_ncols);
00316
00317   } else {
00318     x1 = std::numeric_limits<mtk::Real>::infinity();
00319   }
00320
00321   glp_delete_prob (lp);
00322   glp_free_env ();
00323
00324   delete [] ia;
00325   delete [] ja;
00326   delete [] ar;
00327   delete [] objective;
00328   delete [] rhs;
00329   delete [] err;
00330
00331   return x1;
00332 }
```

18.97 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)

18.97.1 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.

18.98 mtk_grad_1d.cc

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
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00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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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
00067 #ifdef MTK_VERBOSE_WEIGHTS
00068 #include <fstream>
00069 #endif
00070
00071 #include <limits>
00072 #include <algorithm>
00073
00074 #include "mtk_tools.h"
00075
00076 #include "mtk_blas_adapter.h"
00077 #include "mtk_lapack_adapter.h"
00078 #include "mtk_glpk_adapter.h"
00079
00080 #include "mtk_grad_1d.h"
00081
00082 namespace mtk {
00083
00084 std::ostream& operator <<(std::ostream &stream, mtk::Grad1D &in) {
00085
00086   int output_precision{4};
00087   int output_width{8};
00088
00090
00091   stream << "Order of accuracy: " << in.gradient_[0] << std::endl;
00092
```

```
00094
00095   stream << "Interior stencil: " << std::endl;
00096   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00097     stream << std::setprecision(output_precision) <<
00098         std::setw(output_width) << in.gradient_[ii] << ' ';
00099   }
00100   stream << std::endl;
00101
00103
00104   stream << "Weights:" << std::endl;
00105   for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00106     stream << std::setprecision(output_precision) <<
00107         std::setw(output_width) << in.gradient_[ii] << ' ';
00108   }
00109   stream << std::endl;
00110
00112
00113   int offset{2*in.order_accuracy_ + 1};
00114   int mm {};
00115   if (in.order_accuracy_ > mtk::kDefaultOrderAccuracy) {
00116     for (auto ii = 0; ii < in.num_bndy_approxs_ ; ++ii) {
00117       stream << "Boundary row " << ii + 1 << ":" << std::endl;
00118       for (auto jj = 0; jj < in.num_bndy_coeffs_; jj++) {
00119         auto value = in.gradient_[offset + (mm)];
00120         stream << std::setprecision(output_precision) <<
00121         std::setw(output_width) << value << ' ';
00122         mm++;
00123       }
00124       stream << std::endl;
00125       stream << "Sum of elements in boundary row " << ii + 1 << ": " <<
00126         in.sums_rows_mim_bndy_[ii];
00127       stream << std::endl;
00128     }
00129   } else {
00130     stream << "Boundary row 1:" << std::endl;
00131     stream << std::setprecision(output_precision) <<
00132         std::setw(output_width) << in.gradient_[offset + 0] << ' ';
00133     stream << std::setprecision(output_precision) <<
00134         std::setw(output_width) << in.gradient_[offset + 1] << ' ';
00135     stream << std::setprecision(output_precision) <<
00136         std::setw(output_width) << in.gradient_[offset + 2] << ' ';
00137     stream << std::endl;
00138     stream << "Sum of elements in boundary row 1: " <<
00139       in.gradient_[offset + 0] + in.gradient_[offset + 1] +
00140         in.gradient_[offset + 2];
00141     stream << std::endl;
00142   }
00143
00144   return stream;
00145 }
00146 }
00147
00148 mtk::Grad1D::Grad1D():
00149   order_accuracy_(mtk::kDefaultOrderAccuracy),
00150   dim_null_(),
00151   num_bndy_approxs_(),
00152   num_bndy_coeffs_(),
00153   gradient_length_(),
00154   minrow_(),
00155   row_(),
00156   num_feasible_sols_(),
00157   coeffs_interior_(),
00158   prem_apps_(),
00159   weights_crs_(),
00160   weights_cbs_(),
00161   mim_bndy_(),
00162   gradient_(),
00163   mimetic_threshold_(mtk::kDefaultMimeticThreshold),
00164   mimetic_measure_(mtk::kZero),
00165   sums_rows_mim_bndy_() {}
00166
00167 mtk::Grad1D::Grad1D(const Grad1D &grad):
00168   order_accuracy_(grad.order_accuracy_),
00169   dim_null_(grad.dim_null_),
00170   num_bndy_approxs_(grad.num_bndy_approxs_),
00171   num_bndy_coeffs_(grad.num_bndy_coeffs_),
00172   gradient_length_(grad.gradient_length_),
00173   minrow_(grad.minrow_),
00174   row_(grad.row_),
00175   num_feasible_sols_(grad.num_feasible_sols_),
```

```
00176   coeffs_interior_(grad.coeffs_interior_),
00177   prem_apps_(grad.prem_apps_),
00178   weights_crs_(grad.weights_crs_),
00179   weights_cbs_(grad.weights_cbs_),
00180   mim_bndy_(grad.mim_bndy_),
00181   gradient_(grad.gradient_),
00182   mimetic_threshold_(grad.mimetic_threshold_),
00183   mimetic_measure_(grad.mimetic_measure_),
00184   sums_rows_mim_bndy_(grad.sums_rows_mim_bndy_) {}
00185
00186 mtk::Grad1D::~Grad1D() {
00187
00188   delete[] coeffs_interior_;
00189   coeffs_interior_ = nullptr;
00190
00191   delete[] prem_apps_;
00192   prem_apps_ = nullptr;
00193
00194   delete[] weights_crs_;
00195   weights_crs_ = nullptr;
00196
00197   delete[] weights_cbs_;
00198   weights_cbs_ = nullptr;
00199
00200   delete[] mim_bndy_;
00201   mim_bndy_ = nullptr;
00202
00203   delete[] gradient_;
00204   gradient_ = nullptr;
00205 }
00206
00207 bool mtk::Grad1D::ConstructGrad1D(int order_accuracy,
      Real mimetic_threshold) {
00208
00209   #ifdef MTK_PERFORM_PREVENTIONS
00210   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00211   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00212   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00213                       __FILE__, __LINE__, __func__);
00214
00215   if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00216     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00217   }
00218
00219   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00220   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00221   #endif
00222
00223   order_accuracy_ = order_accuracy;
00224   mimetic_threshold_ = mimetic_threshold;
00225
00227   bool abort_construction = ComputeStencilInteriorGrid();
00228
00229   #ifdef MTK_PERFORM_PREVENTIONS
00230   if (!abort_construction) {
00231     std::cerr << "Could NOT complete stage 1." << std::endl;
00232     std::cerr << "Exiting..." << std::endl;
00233     return false;
00234   }
00235   #endif
00236
00237   // At this point, we already have the values for the interior stencil stored
00238   // in the coeffs_interior_ array.
00239
00240   dim_null_ = order_accuracy_/2 - 1;
00241
00242   num_bndy_approxs_ = dim_null_ + 1;
00243
00244   #ifdef MTK_PRECISION_DOUBLE
00245   num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00246   #else
00247   num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00248   #endif
00249
00251
00252   // For this we will follow recommendations given in:
00253   //
00254   // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00255   //
00256   // We will compute the QR Factorization of the transpose, as in the
00257   // following (MATLAB) pseudo-code:
```

```
00258   //
00259   // [Q,R] = qr(V'); % Full QR as defined in
00260   // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00261   //
00262   // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00263   //
00264   // However, given the nature of the Vandermonde matrices we've just
00265   // computed, they all posses the same null-space. Therefore, we impose the
00266   // convention of computing the null-space of the first Vandermonde matrix
00267   // (west boundary).
00268
00269   // In the case of the gradient, the first Vandermonde system has a unique
00270   // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00271   // matrix used to assemble said system, will have an empty null-space.
00272
00273   // Therefore, we only compute a rational basis for the case of order higher
00274   // than second.
00275
00276   if (dim_null_ > 0) {
00277
00278     abort_construction = ComputeRationalBasisNullSpace();
00279
00280     #ifdef MTK_PERFORM_PREVENTIONS
00281     if (!abort_construction) {
00282       std::cerr << "Could NOT complete stage 2.1." << std::endl;
00283       std::cerr << "Exiting..." << std::endl;
00284       return false;
00285     }
00286     #endif
00287   }
00288
00290   abort_construction = ComputePreliminaryApproximations();
00291
00292   #ifdef MTK_PERFORM_PREVENTIONS
00293   if (!abort_construction) {
00294     std::cerr << "Could NOT complete stage 2.2." << std::endl;
00295     std::cerr << "Exiting..." << std::endl;
00296     return false;
00297   }
00298   #endif
00299
00301   abort_construction = ComputeWeights();
00302
00303   #ifdef MTK_PERFORM_PREVENTIONS
00304   if (!abort_construction) {
00305     std::cerr << "Could NOT complete stage 2.3." << std::endl;
00306     std::cerr << "Exiting..." << std::endl;
00307     return false;
00308   }
00309   #endif
00310
00312   if (dim_null_ > 0) {
00313
00314     abort_construction = ComputeStencilBoundaryGrid();
00315
00316     #ifdef MTK_PERFORM_PREVENTIONS
00317     if (!abort_construction) {
00318       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00319       std::cerr << "Exiting..." << std::endl;
00320       return false;
00321     }
00322     #endif
00323   }
00324
00326
00327   // Once we have the following three collections of data:
00328   //   (a) the coefficients for the interior,
00329   //   (b) the coefficients for the boundary (if it applies),
00330   //   (c) and the weights (if it applies),
00331   // we will store everything in the output array:
00332
00333   abort_construction = AssembleOperator();
00334
00335   #ifdef MTK_PERFORM_PREVENTIONS
00336   if (!abort_construction) {
00337     std::cerr << "Could NOT complete stage 3." << std::endl;
00338     std::cerr << "Exiting..." << std::endl;
00339     return false;
00340   }
00341   #endif
00342
```

```
00343   return true;
00344 }
00345
00346 int mtk::Grad1D::num_bndy_coeffs() const {
00347
00348   return num_bndy_coeffs_;
00349 }
00350
00351 mtk::Real *mtk::Grad1D::coeffs_interior() const {
00352
00353   return coeffs_interior_;
00354 }
00355
00356 mtk::Real *mtk::Grad1D::weights_crs() const {
00357
00358   return weights_crs_;
00359 }
00360
00361 mtk::Real *mtk::Grad1D::weights_cbs() const {
00362
00363   return weights_cbs_;
00364 }
00365
00366 int mtk::Grad1D::num_feasible_sols() const {
00367
00368   return num_feasible_sols_;
00369 }
00370
00371 mtk::DenseMatrix mtk::Grad1D::mim_bndy() const {
00372
00373   mtk::DenseMatrix xx(dim_null_ + 1, 3*order_accuracy_/2);
00374
00375   auto counter = 0;
00376   for (auto ii = 0; ii < dim_null_ + 1; ++ii) {
00377     for(auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00378       xx.SetValue(ii,jj, gradient_[2*order_accuracy_ + 1 + counter]);
00379       counter++;
00380     }
00381   }
00382
00383   return xx;
00384 }
00385
00386 std::vector<mtk::Real> mtk::Grad1D::sums_rows_mim_bndy() const {
00387
00388   return sums_rows_mim_bndy_;
00389 }
00390
00391 mtk::Real mtk::Grad1D::mimetic_measure() const {
00392
00393   return mimetic_measure_;
00394 }
00395
00396 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
    mtk::Real west,
00397                                                   mtk::Real east,
00398                                                   int num_cells_x) const {
00399
00400   int nn{num_cells_x}; // Number of cells on the grid.
00401
00402   #ifdef MTK_PERFORM_PREVENTIONS
00403   mtk::Tools::Prevent(east < west, __FILE__, __LINE__, __func__);
00404   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00405   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00406   #endif
00407
00408   mtk::Real delta_x = (east - west)/((mtk::Real) num_cells_x);
00409
00410   mtk::Real inv_delta_x{mtk::kOne/delta_x};
00411
00412   int gg_num_rows = nn + 1;
00413   int gg_num_cols = nn + 2;
00414   int elements_per_row = num_bndy_coeffs_;
00415   int num_extra_rows = order_accuracy_/2;
00416
00417   // Output matrix featuring sizes for gradient operators.
00418   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00419
00421
00422   auto ee_index = 0;
00423   for (auto ii = 0; ii < num_extra_rows; ii++) {
```

```
00424     auto cc = 0;
00425     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00426       if(cc >= elements_per_row) {
00427         out.SetValue(ii, jj, mtk::kZero);
00428       } else {
00429         out.SetValue(ii,jj,
00430                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00431         cc++;
00432       }
00433     }
00434   }
00435
00437
00438   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00439     auto jj = ii - num_extra_rows + 1;
00440     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00441       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00442     }
00443   }
00444
00446
00447   ee_index = 0;
00448   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00449     auto cc = 0;
00450     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00451       if(cc >= elements_per_row) {
00452         out.SetValue(ii,jj,mtk::kZero);
00453       } else {
00454         out.SetValue(ii,jj,
00455                      -gradient_[2*order_accuracy_ + 1 +
00456 ee_index++]*inv_delta_x);
00457         cc++;
00458       }
00459      }
00460   }
00461
00462   return out;
00463 }
00464
00465 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
00466   const UniStgGrid1D &grid) const {
00467
00468   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00469
00470   #ifdef MTK_PERFORM_PREVENTIONS
00471   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00472   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00473   #endif
00474
00475   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00476
00477   int gg_num_rows = nn + 1;
00478   int gg_num_cols = nn + 2;
00479   int elements_per_row = num_bndy_coeffs_;
00480   int num_extra_rows = order_accuracy_/2;
00481
00482   // Output matrix featuring sizes for gradient operators.
00483   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00484
00486
00487   auto ee_index = 0;
00488   for (auto ii = 0; ii < num_extra_rows; ii++) {
00489     auto cc = 0;
00490     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00491       if(cc >= elements_per_row) {
00492         out.SetValue(ii, jj, mtk::kZero);
00493       } else {
00494         out.SetValue(ii,jj,
00495                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00496         cc++;
00497       }
00498     }
00499   }
00500
00502
00503   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00504     auto jj = ii - num_extra_rows + 1;
00505     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00506       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00507     }
00508   }
```

```
00509
00511
00512   ee_index = 0;
00513   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00514     auto cc = 0;
00515     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00516       if(cc >= elements_per_row) {
00517         out.SetValue(ii,jj,mtk::kZero);
00518       } else {
00519         out.SetValue(ii,jj,
00520                      -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00521         cc++;
00522       }
00523      }
00524   }
00525
00526   return out;
00527 }
00528
00529 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix
      (
00530   int num_cells_x) const {
00531
00532   int nn{num_cells_x}; // Number of cells on the grid.
00533
00534   #ifdef MTK_PERFORM_PREVENTIONS
00535   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00536   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00537   #endif
00538
00539   int gg_num_rows = nn + 1;
00540   int gg_num_cols = nn + 2;
00541   int elements_per_row = num_bndy_coeffs_;
00542   int num_extra_rows = order_accuracy_/2;
00543
00544   // Output matrix featuring sizes for gradient operators.
00545   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00546
00548
00549   auto ee_index = 0;
00550   for (auto ii = 0; ii < num_extra_rows; ii++) {
00551     auto cc = 0;
00552     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00553       if(cc >= elements_per_row) {
00554         out.SetValue(ii, jj, mtk::kZero);
00555       } else {
00556         out.SetValue(ii,jj,
00557                      gradient_[2*order_accuracy_ + 1 + ee_index++]);
00558         cc++;
00559       }
00560     }
00561   }
00562
00564
00565   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00566     auto jj = ii - num_extra_rows + 1;
00567     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00568       out.SetValue(ii, jj, coeffs_interior_[cc]);
00569     }
00570   }
00571
00573
00574   ee_index = 0;
00575   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00576     auto cc = 0;
00577     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00578       if(cc >= elements_per_row) {
00579         out.SetValue(ii,jj,mtk::kZero);
00580       } else {
00581         out.SetValue(ii,jj,
00582                      -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00583         cc++;
00584       }
00585      }
00586   }
00587
00588   return out;
00589 }
00590
00591 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00592
```

```
00594
00595   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00596
00597   try {
00598     pp = new mtk::Real[order_accuracy_];
00599   } catch (std::bad_alloc &memory_allocation_exception) {
00600     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00601       std::endl;
00602     std::cerr << memory_allocation_exception.what() << std::endl;
00603   }
00604   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00605
00606   #ifdef MTK_PRECISION_DOUBLE
00607   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00608   #else
00609   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00610   #endif
00611
00612   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00613     pp[ii] = pp[ii - 1] + mtk::kOne;
00614   }
00615
00616   #if MTK_VERBOSE_LEVEL > 3
00617   std::cout << "pp =" << std::endl;
00618   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00619     std::cout << std::setw(12) << pp[ii];
00620   }
00621   std::cout << std::endl << std::endl;
00622   #endif
00623
00625
00626   bool transpose{false};
00627
00628   mtk::DenseMatrix vander_matrix(pp,order_accuracy_,order_accuracy_,transpose);
00629
00630   #if MTK_VERBOSE_LEVEL > 4
00631   std::cout << "vander_matrix = " << std::endl;
00632   std::cout << vander_matrix << std::endl << std::endl;
00633   #endif
00634
00636
00637   try {
00638     coeffs_interior_ = new mtk::Real[order_accuracy_];
00639   } catch (std::bad_alloc &memory_allocation_exception) {
00640     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00641       std::endl;
00642     std::cerr << memory_allocation_exception.what() << std::endl;
00643   }
00644   memset(coeffs_interior_, mtk::kZero,
00645 sizeof(coeffs_interior_[0])*order_accuracy_);
00646
00647   coeffs_interior_[1] = mtk::kOne;
00648
00649   #if MTK_VERBOSE_LEVEL > 3
00650   std::cout << "oo =" << std::endl;
00651   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00652     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00653   }
00654   std::cout << std::endl;
00655   #endif
00656
00658
00659   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00660                                                 coeffs_interior_)};
00661
00662   #ifdef MTK_PERFORM_PREVENTIONS
00663   if (!info) {
00664     std::cout << "System solved! Interior stencil attained!" << std::endl;
00665     std::cout << std::endl;
00666   }
00667   else {
00668     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00669     std::cerr << "Exiting..." << std::endl;
00670     return false;
00671   }
00672   #endif
00673
00674   #if MTK_VERBOSE_LEVEL > 3
00675   std::cout << "coeffs_interior_ =" << std::endl;
00676   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00677     std::cout << std::setw(12) << coeffs_interior_[ii];
```

```
00678   }
00679   std::cout << std::endl << std::endl;
00680   #endif
00681
00682   delete [] pp;
00683   pp = nullptr;
00684
00685   return true;
00686 }
00687
00688 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00689
00691
00692   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
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[1] = 1.0/2.0;
00705   #else
00706   gg[1] = 1.0f/2.0f;
00707   #endif
00708   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00709     gg[ii] = gg[ii - 1] + mtk::kOne;
00710   }
00711
00712   #if MTK_VERBOSE_LEVEL > 3
00713   std::cout << "gg =" << 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
00721
00722   bool tran{true}; // Should I transpose the Vandermonde matrix.
00723
00724   mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00725
00726   #if MTK_VERBOSE_LEVEL > 4
00727   std::cout << "aa_west_t =" << std::endl;
00728   std::cout << aa_west_t << std::endl;
00729   #endif
00730
00732
00733   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (aa_west_t));
00734
00735   #if MTK_VERBOSE_LEVEL > 3
00736   std::cout << "qq_t = " << std::endl;
00737   std::cout << qq_t << std::endl;
00738   #endif
00739
00741
00742   int kk_num_rows{num_bndy_coeffs_};
00743   int kk_num_cols{dim_null_};
00744
00745   mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00746
00747   // In the case of the gradient, even though we must solve for a null-space
00748   // of dimension 2, we must only extract ONE basis for the kernel.
00749   // We perform this extraction here:
00750
00751   int aux_{kk_num_rows - kk_num_cols};
00752   for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00753     aux_--;
00754     for (auto jj = 0; jj < kk_num_rows; jj++) {
00755       kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00756         qq_t.data()[ii*num_bndy_coeffs_ + jj];
00757     }
00758   }
00759
00760   #if MTK_VERBOSE_LEVEL > 2
00761   std::cout << "kk =" << std::endl;
```

```
00762   std::cout << kk << std::endl;
00763   std::cout << "kk.num_rows() = " << kk.num_rows() << std::endl;
00764   std::cout << "kk.num_cols() = " << kk.num_cols() << std::endl;
00765   std::cout << std::endl;
00766   #endif
00767
00769
00770   // Scale thus requesting that the last entries of the attained basis for the
00771   // null-space, adopt the pattern we require.
00772   // Essentially we will implement the following MATLAB pseudo-code:
00773   //  scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00774   //  SK = kk*scalers
00775   // where SK is the scaled null-space.
00776
00777   // In this point, we almost have all the data we need correctly allocated
00778   // in memory. We will create the matrix iden_, and elements we wish to scale
00779   // in the kk array. Using the concept of the leading dimension, we could just
00780   // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00781   // GET how does it work. So I will just create a matrix with the content of
00782   // this array that we need, solve for the scalers and then scale the
00783   // whole kk:
00784
00785   // We will then create memory for that sub-matrix of kk (subk).
00786
00787   mtk::DenseMatrix subk(dim_null_, dim_null_);
00788
00789   auto zz = 0;
00790   for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00791     for (auto jj = 0; jj < dim_null_; jj++) {
00792       subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00793     }
00794     zz++;
00795   }
00796
00797   #if MTK_VERBOSE_LEVEL > 4
00798   std::cout << "subk =" << std::endl;
00799   std::cout << subk << std::endl;
00800   #endif
00801
00802   subk.Transpose();
00803
00804   #if MTK_VERBOSE_LEVEL > 4
00805   std::cout << "subk_t =" << std::endl;
00806   std::cout << subk << std::endl;
00807   #endif
00808
00809   bool padded{false};
00810   tran = false;
00811
00812   mtk::DenseMatrix iden(dim_null_, padded, tran);
00813
00814   #if MTK_VERBOSE_LEVEL > 4
00815   std::cout << "iden =" << std::endl;
00816   std::cout << iden << std::endl;
00817   #endif
00818
00819   // Solve the system to compute the scalers.
00820   // An example of the system to solve, for k = 8, is:
00821   //
00822   // subk*scalers = iden or
00823   //
00824   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00825   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00826   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00827   //
00828   // Notice this is a nrhs = 3 system.
00829   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00830   // will be stored in the created identity matrix.
00831   // Let us first transpose subk (because of LAPACK):
00832
00833   int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00834
00835   #ifdef MTK_PERFORM_PREVENTIONS
00836   if (!info) {
00837     std::cout << "System successfully solved!" <<
00838       std::endl;
00839   } else {
00840     std::cerr << "Something went wrong solving system! info = " << info <<
00841       std::endl;
00842     std::cerr << "Exiting..." << std::endl;
00843     return false;
```

```
00844   }
00845   std::cout << std::endl;
00846   #endif
00847
00848   #if MTK_VERBOSE_LEVEL > 4
00849   std::cout << "Computed scalers:" << std::endl;
00850   std::cout << iden << std::endl;
00851   #endif
00852
00853   // Multiply the two matrices to attain a scaled basis for null-space.
00854
00855   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00856
00857   #if MTK_VERBOSE_LEVEL > 4
00858   std::cout << "Rational basis for the null-space:" << std::endl;
00859   std::cout << rat_basis_null_space_ << std::endl;
00860   #endif
00861
00862   // At this point, we have a rational basis for the null-space, with the
00863   // pattern we need! :)
00864
00865   delete [] gg;
00866   gg = nullptr;
00867
00868   return true;
00869 }
00870
00871 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00872
00874
00875   mtk::Real *gg{}; // Generator vector for the first approximation.
00876
00877   try {
00878     gg = new mtk::Real[num_bndy_coeffs_];
00879   } catch (std::bad_alloc &memory_allocation_exception) {
00880     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00881       std::endl;
00882     std::cerr << memory_allocation_exception.what() << std::endl;
00883   }
00884   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00885
00886   #ifdef MTK_PRECISION_DOUBLE
00887   gg[1] = 1.0/2.0;
00888   #else
00889   gg[1] = 1.0f/2.0f;
00890   #endif
00891   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00892     gg[ii] = gg[ii - 1] + mtk::kOne;
00893   }
00894
00895   #if MTK_VERBOSE_LEVEL > 3
00896   std::cout << "gg0 =" << std::endl;
00897   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00898     std::cout << std::setw(12) << gg[ii];
00899   }
00900   std::cout << std::endl << std::endl;
00901   #endif
00902
00903   // Allocate 2D array to store the collection of preliminary approximations.
00904   try {
00905     prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00906   } catch (std::bad_alloc &memory_allocation_exception) {
00907     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00908 std::endl;
00909     std::cerr << memory_allocation_exception.what() << std::endl;
00910   }
00911   memset(prem_apps_,
00912          mtk::kZero,
00913          sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00914
00916
00917   for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00918
00919     // Re-check new generator vector for every iteration except for the first.
00920     #if MTK_VERBOSE_LEVEL > 3
00921     if (ll > 0) {
00922       std::cout << "gg_" << ll << " =" << std::endl;
00923       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00924         std::cout << std::setw(12) << gg[ii];
00925       }
00926       std::cout << std::endl << std::endl;
```

```
00927     }
00928     #endif
00929
00931
00932     bool transpose{false};
00933
00934     mtk::DenseMatrix aa(gg,
00935                         num_bndy_coeffs_, order_accuracy_ + 1,
00936                         transpose);
00937
00938     #if MTK_VERBOSE_LEVEL > 4
00939     std::cout << "aa_" << ll << " =" << std::endl;
00940     std::cout << aa << std::endl;
00941     #endif
00942
00944
00945     mtk::Real *ob{};
00946
00947     auto ob_ld = num_bndy_coeffs_;
00948
00949     try {
00950       ob = new mtk::Real[ob_ld];
00951     } catch (std::bad_alloc &memory_allocation_exception) {
00952       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00953         std::endl;
00954       std::cerr << memory_allocation_exception.what() << std::endl;
00955     }
00956     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00957
00958     ob[1] = mtk::kOne;
00959
00960     #if MTK_VERBOSE_LEVEL > 3
00961     std::cout << "ob = " << std::endl << std::endl;
00962     for (auto ii = 0; ii < ob_ld; ++ii) {
00963       std::cout << std::setw(12) << ob[ii] << std::endl;
00964     }
00965     std::cout << std::endl;
00966     #endif
00967
00969
00970     // However, this is an under-determined system of equations. So we can not
00971     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00972     // our LAPACKAdapter class.
00973
00974     int info_{
00975       mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
      , ob_ld)};
00976
00977     #ifdef MTK_PERFORM_PREVENTIONS
00978     if (!info_) {
00979       std::cout << "System successfully solved!" << std::endl << std::endl;
00980     } else {
00981       std::cerr << "Error solving system! info = " << info_ << std::endl;
00982       return false;
00983     }
00984     #endif
00985
00986     #if MTK_VERBOSE_LEVEL > 3
00987     std::cout << "ob =" << std::endl;
00988     for (auto ii = 0; ii < ob_ld; ++ii) {
00989       std::cout << std::setw(12) << ob[ii] << std::endl;
00990     }
00991     std::cout << std::endl;
00992     #endif
00993
00995
00996     // This implies a DAXPY operation. However, we must construct the arguments
00997     // for this operation.
00998
01000     // Save them into the ob_bottom array:
01001
01002     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
01003
01004     try {
01005       ob_bottom = new mtk::Real[dim_null_];
01006     } catch (std::bad_alloc &memory_allocation_exception) {
01007       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01008         std::endl;
01009       std::cerr << memory_allocation_exception.what() << std::endl;
01010     }
01011     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
```

```
01012
01013     for (auto ii = 0; ii < dim_null_; ++ii) {
01014       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
01015     }
01016
01017     #if MTK_VERBOSE_LEVEL > 3
01018     std::cout << "ob_bottom =" << std::endl;
01019     for (auto ii = 0; ii < dim_null_; ++ii) {
01020       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
01021     }
01022     std::cout << std::endl;
01023     #endif
01024
01026
01027     // We must computed an scaled ob, sob, using the scaled null-space in
01028     // rat_basis_null_space_.
01029     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
01030     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
01031     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
01032
01033     #if MTK_VERBOSE_LEVEL > 4
01034     std::cout << "Rational basis for the null-space:" << std::endl;
01035     std::cout << rat_basis_null_space_ << std::endl;
01036     #endif
01037
01038     mtk::Real alpha{-mtk::kOne};
01039     mtk::Real beta{mtk::kOne};
01040
01041     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
01042                                   ob_bottom, beta, ob);
01043
01044     #if MTK_VERBOSE_LEVEL > 3
01045     std::cout << "scaled ob:" << std::endl;
01046     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01047       std::cout << std::setw(12) << ob[ii] << std::endl;
01048     }
01049     std::cout << std::endl;
01050     #endif
01051
01052     // We save the recently scaled solution, into an array containing these.
01053     // We can NOT start building the pi matrix, simply because I want that part
01054     // to be separated since its construction depends on the algorithm we want
01055     // to implement.
01056
01057     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01058       prem_apps_[ii*num_bndy_approxs_ + ll] = ob[ii];
01059     }
01060
01061     // After the first iteration, simply shift the entries of the last
01062     // generator vector used:
01063     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01064       gg[ii]--;
01065     }
01066
01067     // Garbage collection for this loop:
01068     delete[] ob;
01069     ob = nullptr;
01070
01071     delete[] ob_bottom;
01072     ob_bottom = nullptr;
01073   } // End of: for (ll = 0; ll < dim_null; ll++);
01074
01075   #if MTK_VERBOSE_LEVEL > 4
01076   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
01077   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01078     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01079       std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
01080     }
01081     std::cout << std::endl;
01082   }
01083   std::cout << std::endl;
01084   #endif
01085
01086   delete[] gg;
01087   gg = nullptr;
01088
01089   return true;
01090 }
01091
01092 bool mtk::Grad1D::ComputeWeights() {
01093
```

```
01094   // Matrix to compute the weights as in the CRSA.
01095   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01096
01098
01099   // Assemble the pi matrix using:
01100   // 1. The collection of scaled preliminary approximations.
01101   // 2. The collection of coefficients approximating at the interior.
01102   // 3. The scaled basis for the null-space.
01103
01104   // 1.1. Process array of scaled preliminary approximations.
01105
01106   // These are queued in scaled_solutions. Each one of these, will be a column
01107   // of the pi matrix:
01108   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01109     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01110       pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
01111         prem_apps_[ii*num_bndy_approxs_ + jj];
01112     }
01113   }
01114
01115   // 1.2. Add columns from known stencil approximating at the interior.
01116
01117   // However, these must be padded by zeros, according to their position in the
01118   // final pi matrix:
01119   auto mm = 1;
01120   for (auto jj = num_bndy_approxs_; jj < order_accuracy_; ++jj) {
01121     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01122       auto de = (ii + mm)*(2*(num_bndy_approxs_ - 1) +
01123         (order_accuracy_/2 + 1)) + jj;
01124       pi.data()[de] = coeffs_interior_[ii];
01125     }
01126     ++mm;
01127   }
01128
01129   rat_basis_null_space_.OrderColMajor();
01130
01131   #if MTK_VERBOSE_LEVEL > 4
01132   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01133   std::cout << rat_basis_null_space_ << std::endl;
01134   #endif
01135
01136   // 1.3. Add final set of columns: rational basis for null-space.
01137
01138   for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
01139        jj < num_bndy_coeffs_ - 1; ++jj) {
01140     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01141       auto og =
01142         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
01143       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
01144       pi.data()[de] = rat_basis_null_space_.data()[og];
01145     }
01146   }
01147
01148   #if MTK_VERBOSE_LEVEL > 4
01149   std::cout << "coeffs_interior_ =" << std::endl;
01150   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01151     std::cout << std::setw(12) << coeffs_interior_[ii];
01152   }
01153   std::cout << std::endl << std::endl;
01154   #endif
01155
01156   #if MTK_VERBOSE_LEVEL > 4
01157   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01158   std::cout << pi << std::endl;
01159   #endif
01160
01162
01163   // This imposes the mimetic condition.
01164
01165   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
01166
01167   try {
01168     hh = new mtk::Real[num_bndy_coeffs_];
01169   } catch (std::bad_alloc &memory_allocation_exception) {
01170     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01171       std::endl;
01172     std::cerr << memory_allocation_exception.what() << std::endl;
01173   }
01174   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01175
01176   hh[0] = -mtk::kOne;
```

```
01177   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01178     auto aux_xx = mtk::kZero;
01179     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01180       aux_xx += coeffs_interior_[jj];
01181     }
01182     hh[ii] = -mtk::kOne*aux_xx;
01183   }
01184
01186
01187   // That is, we construct a system, to solve for the weights.
01188
01189   // Once again we face the challenge of solving with LAPACK. However, for the
01190   // CRSA, this matrix PI is over-determined, since it has more rows than
01191   // unknowns. However, according to the theory, the solution to this system is
01192   // unique. We will use dgels_.
01193
01194   try {
01195     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01196   } catch (std::bad_alloc &memory_allocation_exception) {
01197     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01198       std::endl;
01199     std::cerr << memory_allocation_exception.what() << std::endl;
01200   }
01201   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01202
01203   int weights_ld{pi.num_cols() + 1};
01204
01205   // Preserve hh.
01206   std::copy(hh, hh + weights_ld, weights_cbs_);
01207
01208   pi.Transpose();
01209
01210   int info{
01211     mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01212                                                     weights_cbs_, weights_ld)
01213   };
01214
01215   #ifdef MTK_PERFORM_PREVENTIONS
01216   if (!info) {
01217     std::cout << "System successfully solved!" << std::endl << std::endl;
01218   } else {
01219     std::cerr << "Error solving system! info = " << info << std::endl;
01220     return false;
01221   }
01222   #endif
01223
01224   #if MTK_VERBOSE_LEVEL > 3
01225   std::cout << "hh =" << std::endl;
01226   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01227     std::cout << std::setw(11) << hh[ii] << std::endl;
01228   }
01229   std::cout << std::endl;
01230   #endif
01231
01232   // Preserve the original weights for research.
01233
01234   try {
01235     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01236   } catch (std::bad_alloc &memory_allocation_exception) {
01237     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01238       std::endl;
01239     std::cerr << memory_allocation_exception.what() << std::endl;
01240   }
01241   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01242
01243   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01244
01245   #if MTK_VERBOSE_LEVEL > 3
01246   std::cout << "weights_CRSA + lambda =" << std::endl;
01247   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01248     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01249   }
01250   std::cout << std::endl;
01251   #endif
01252
01254
01255   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01256
01258
01259     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01260
```

```
01261     // 6.1. Insert preliminary approximations to first set of columns.
01262
01263     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01264       for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01265         phi.data()[ii*(order_accuracy_) + jj] =
01266           prem_apps_[ii*num_bndy_approxs_ + jj];
01267       }
01268     }
01269
01270     // 6.2. Skip a column and negate preliminary approximations.
01271
01272     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01273       for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01274         auto de = (ii+ order_accuracy_ - num_bndy_approxs_+ jj*order_accuracy_);
01275         auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01276         phi.data()[de] = -prem_apps_[og];
01277       }
01278     }
01279
01280     // 6.3. Flip negative columns up-down.
01281
01282     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01283       for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01284         auto aux = phi.data()[ii*order_accuracy_ + jj];
01285         phi.data()[ii*order_accuracy_ + jj] =
01286           phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj];
01287         phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01288       }
01289     }
01290
01291     // 6.4. Insert stencil.
01292
01293     auto mm = 0;
01294     for (auto jj = num_bndy_approxs_; jj < num_bndy_approxs_ +  1; jj++) {
01295       for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01296         if (ii == 0) {
01297           phi.data()[jj] = 0.0;
01298         } else {
01299           phi.data()[(ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01300         }
01301       }
01302       mm++;
01303     }
01304
01305     #if MTK_VERBOSE_LEVEL > 4
01306     std::cout << "phi =" << std::endl;
01307     std::cout << phi << std::endl;
01308     #endif
01309
01311
01312     mtk::Real *lamed{};  // Used to build big lambda.
01313
01314     try {
01315       lamed = new mtk::Real[num_bndy_approxs_ - 1];
01316     } catch (std::bad_alloc &memory_allocation_exception) {
01317       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01318         std::endl;
01319       std::cerr << memory_allocation_exception.what() << std::endl;
01320     }
01321     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01322
01323     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01324       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01325     }
01326
01327     #if MTK_VERBOSE_LEVEL > 3
01328     std::cout << "lamed =" << std::endl;
01329     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01330       std::cout << std::setw(12) << lamed[ii] << std::endl;
01331     }
01332     std::cout << std::endl;
01333     #endif
01334
01335     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01336       mtk::Real temp = mtk::kZero;
01337       for(auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01338         temp = temp +
01339           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01340       }
01341       hh[ii] = hh[ii] - temp;
01342     }
```

```
01343
01344     #if MTK_VERBOSE_LEVEL > 3
01345     std::cout << "big_lambda =" << std::endl;
01346     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01347       std::cout << std::setw(12) << hh[ii] << std::endl;
01348     }
01349     std::cout << std::endl;
01350     #endif
01351
01353
01354     #ifdef MTK_VERBOSE_WEIGHTS
01355     int copy_result{1};
01356     #else
01357     int copy_result{};
01358     #endif
01359
01360     int minrow_{std::numeric_limits<int>::infinity()};
01361
01362     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01363     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01364
01365     mtk::Real normerr_; // Norm of the error for the solution on each row.
01366
01367     #ifdef MTK_VERBOSE_WEIGHTS
01368     std::ofstream table("grad_1d_" + std::to_string(order_accuracy_) +
01369       "_weights.tex");
01370
01371     table << "\\begin{tabular}[c]{c";
01372     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01373       table << 'c';
01374     }
01375     table << ":c}\n\\toprule\nRow & ";
01376     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01377       table << "$ q_{" + std::to_string(ii) + "}$ &";
01378     }
01379     table << " Relative error \\\\\n\\midrule\n";
01380     #endif
01381
01382     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01383       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01384                                                           order_accuracy_ + 1,
01385                                                           order_accuracy_,
01386                                                           order_accuracy_,
01387                                                           hh,
01388                                                           weights_cbs_,
01389                                                           row_,
01390                                                           mimetic_threshold_,
01391                                                           copy_result);
01392       mtk::Real aux{normerr_/norm};
01393
01394       #if MTK_VERBOSE_LEVEL > 2
01395       std::cout << "Relative norm: " << aux << " " << std::endl;
01396       std::cout << std::endl;
01397       #endif
01398
01399       num_feasible_sols_ = num_feasible_sols_ +
01400         (int) (normerr_ != std::numeric_limits<mtk::Real>::infinity());
01401
01402       if (aux < minnorm) {
01403         minnorm = aux;
01404         minrow_= row_;
01405       }
01406
01407       #ifdef MTK_VERBOSE_WEIGHTS
01408       table << std::to_string(row_ + 1) << " & ";
01409       if (normerr_ != std::numeric_limits<mtk::Real>::infinity()) {
01410         for (int ii = 1; ii <= order_accuracy_; ++ii) {
01411           table << std::to_string(weights_cbs_[ii - 1]) + " & ";
01412         }
01413         table << std::to_string(aux) << " \\\\" << std::endl;
01414       } else {
01415         table << "\\multicolumn{" << std::to_string(order_accuracy_) <<
01416           "}{c}{$\\emptyset$} & ";
01417         table << " - \\\\" << std::endl;
01418       }
01419       #endif
01420     }
01421
01422     #ifdef MTK_VERBOSE_WEIGHTS
```

```
01423     table << "\\midrule" << std::endl;
01424     table << "CRS weights:";
01425     for (int ii = 1; ii <= order_accuracy_; ++ii) {
01426       table << " & " << std::to_string(weights_crs_[ii - 1]);
01427     }
01428     table << " & - \\\\\n\\bottomrule\n\\end{tabular}" << std::endl;
01429     table.close();
01430     #endif
01431
01432     #if MTK_VERBOSE_LEVEL > 3
01433     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01434       std::endl;
01435     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01436       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01437     }
01438     std::cout << std::endl;
01439     #endif
01440
01442
01443     // After we know which row yields the smallest relative norm that row is
01444     // chosen to be the objective function and the result of the optimizer is
01445     // chosen to be the new weights_.
01446
01447     #if MTK_VERBOSE_LEVEL > 2
01448     std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01449       minrow_ + 1 << std::endl;
01450     std::cout << std::endl;
01451     #endif
01452
01453     copy_result = 1;
01454     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
    data(),
01455                                                         order_accuracy_ + 1,
01456                                                         order_accuracy_,
01457                                                         order_accuracy_,
01458                                                         hh,
01459                                                         weights_cbs_,
01460                                                         minrow_,
01461                                                         mimetic_threshold_,
01462                                                         copy_result);
01463     mtk::Real aux_{normerr_/norm};
01464     #if MTK_VERBOSE_LEVEL > 2
01465     std::cout << "Relative norm: " << aux_ << std::endl;
01466     std::cout << std::endl;
01467     #endif
01468
01469     delete [] lamed;
01470     lamed = nullptr;
01471   }
01472
01473   delete [] hh;
01474   hh = nullptr;
01475
01476   return true;
01477 }
01478
01479 bool mtk::Grad1D::ComputeStencilBoundaryGrid(void) {
01480
01481   #if MTK_VERBOSE_LEVEL > 3
01482   std::cout << "weights_* + lambda =" << std::endl;
01483   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01484     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01485   }
01486   std::cout << std::endl;
01487   #endif
01488
01490
01491   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01492
01493   try {
01494     lambda = new mtk::Real[dim_null_];
01495   } catch (std::bad_alloc &memory_allocation_exception) {
01496     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01497       std::endl;
01498     std::cerr << memory_allocation_exception.what() << std::endl;
01499   }
01500   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01501
01502   for (auto ii = 0; ii < dim_null_; ++ii) {
01503     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01504   }
```

```
01505
01506   #if MTK_VERBOSE_LEVEL > 3
01507   std::cout << "lambda =" << std::endl;
01508   for (auto ii = 0; ii < dim_null_; ++ii) {
01509     std::cout << std::setw(12) << lambda[ii] << std::endl;
01510   }
01511   std::cout << std::endl;
01512   #endif
01513
01515
01516   mtk::Real *alpha{}; // Collection of alpha values.
01517
01518   try {
01519     alpha = new mtk::Real[dim_null_];
01520   } catch (std::bad_alloc &memory_allocation_exception) {
01521     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01522       std::endl;
01523     std::cerr << memory_allocation_exception.what() << std::endl;
01524   }
01525   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01526
01527   for (auto ii = 0; ii < dim_null_; ++ii) {
01528     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01529   }
01530
01531   #if MTK_VERBOSE_LEVEL > 3
01532   std::cout << "alpha =" << std::endl;
01533   for (auto ii = 0; ii < dim_null_; ++ii) {
01534     std::cout << std::setw(12) << alpha[ii] << std::endl;
01535   }
01536   std::cout << std::endl;
01537   #endif
01538
01540
01541   try {
01542     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
01543   } catch (std::bad_alloc &memory_allocation_exception) {
01544     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01545       std::endl;
01546     std::cerr << memory_allocation_exception.what() << std::endl;
01547   }
01548   memset(mim_bndy_,
01549          mtk::kZero,
01550          sizeof(mim_bndy_[0])*num_bndy_coeffs_*num_bndy_approxs_);
01551
01552   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01553     for (auto jj = 0; jj < (num_bndy_approxs_ - 1); ++jj) {
01554       mim_bndy_[ii*num_bndy_approxs_ + jj] =
01555         prem_apps_[ii*num_bndy_approxs_ + jj] +
01556         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01557     }
01558   }
01559
01560   for(auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01561     mim_bndy_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)] =
01562       prem_apps_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)];
01563   }
01564
01565   #if MTK_VERBOSE_LEVEL > 4
01566   std::cout << "Collection of mimetic approximations:" << std::endl;
01567   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01568     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01569       std::cout << std::setw(13) << mim_bndy_[ii*num_bndy_approxs_ + jj];
01570     }
01571     std::cout << std::endl;
01572   }
01573   std::cout << std::endl;
01574   #endif
01575
01577
01578   for (auto ii = 0; ii < num_bndy_approxs_; ++ii) {
01579     sums_rows_mim_bndy_.push_back(mtk::kZero);
01580
01581
01582
01583
01584     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01585       sums_rows_mim_bndy_[ii] += mim_bndy_[jj*num_bndy_approxs_ + ii];
01586     }
01587   }
01588
```

```
01589     mimetic_measure_ = *std::max_element(sums_rows_mim_bndy_.begin(),
01590                                          sums_rows_mim_bndy_.end());
01591
01592   #if MTK_VERBOSE_LEVEL > 3
01593   std::cout << "Row-wise sum of mimetic approximations:" << std::endl;
01594   for (auto ii = 0; ii < num_bndy_approxs_; ++ii) {
01595     std::cout << std::setw(13) << sums_rows_mim_bndy_[ii];
01596   }
01597   std::cout << std::endl;
01598   std::cout << std::endl;
01599   #endif
01600
01601   delete[] lambda;
01602   lambda = nullptr;
01603
01604   delete[] alpha;
01605   alpha = nullptr;
01606
01607   return true;
01608 }
01609
01610 bool mtk::Grad1D::AssembleOperator(void) {
01611
01612   // The output array will have this form:
01613   // 1. The first entry of the array will contain the used order kk.
01614   // 2. The second entry of the array will contain the collection of
01615   // approximating coefficients for the interior of the grid.
01616   // 3. The third entry will contain a collection of weights.
01617   // 4. The next dim_null - 1 entries will contain the collections of
01618   // approximating coefficients for the west boundary of the grid.
01619
01620   gradient_length_ = 1 + order_accuracy_ + order_accuracy_ +
01621     num_bndy_approxs_*num_bndy_coeffs_;
01622
01623   #if MTK_VERBOSE_LEVEL > 2
01624   std::cout << "gradient_length_ = " << gradient_length_ << std::endl;
01625   #endif
01626
01627   try {
01628     gradient_ = new mtk::Real[gradient_length_];
01629   } catch (std::bad_alloc &memory_allocation_exception) {
01630     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01631       std::endl;
01632     std::cerr << memory_allocation_exception.what() << std::endl;
01633   }
01634   memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01635
01637
01638   gradient_[0] = order_accuracy_;
01639
01642
01643   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01644     gradient_[ii + 1] = coeffs_interior_[ii];
01645   }
01646
01648
01649   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01650     gradient_[(order_accuracy_ + 1) + ii] = weights_cbs_[ii];
01651   }
01652
01655
01656   int offset{2*order_accuracy_ + 1};
01657
01658   int aux {}; // Auxiliary variable.
01659
01660   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01661     for (auto ii = 0; ii < num_bndy_approxs_ ; ii++) {
01662       for (auto jj = 0; jj < num_bndy_coeffs_; jj++) {
01663         gradient_[offset + aux] = mim_bndy_[jj*num_bndy_approxs_ + ii];
01664         aux++;
01665       }
01666     }
01667   } else {
01668     gradient_[offset + 0] = prem_apps_[0];
01669     gradient_[offset + 1] = prem_apps_[1];
01670     gradient_[offset + 2] = prem_apps_[2];
01671   }
01672
01673   #if MTK_VERBOSE_LEVEL > 1
01674   std::cout << "1D " << order_accuracy_ << "-order grad built!" << std::endl;
01675   std::cout << std::endl;
```

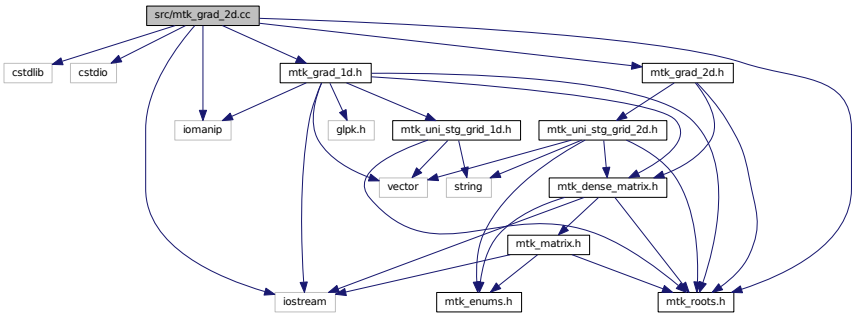
```
01676   #endif
01677
01678   return true;
01679 }
```

18.99 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:



18.99.1 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.

18.100 mtk_grad_2d.cc

```
00001
00011 /*
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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
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_2d.h"
00066
00067 mtk::Grad2D::Grad2D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Grad2D::Grad2D(const Grad2D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad2D::~Grad2D() {}
00076
00077 bool mtk::Grad2D::ConstructGrad2D(const
      mtk::UniStgGrid2D &grid,
00078                                   int order_accuracy,
00079                                   mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083
00084   int mx = num_cells_x + 1;  // Gx vertical dimension
00085   int nx = num_cells_x + 2;  // Gx horizontal dimension
00086   int my = num_cells_y + 1;  // Gy vertical dimension
00087   int ny = num_cells_y + 2;  // Gy horizontal dimension
00088
00089   mtk::Grad1D grad;
00090
00091   bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00092
00093   #ifdef MTK_PERFORM_PREVENTIONS
00094   if (!info) {
00095     std::cerr << "Mimetic grad could not be built." << std::endl;
00096     return info;
00097   }
00098   #endif
00099
```

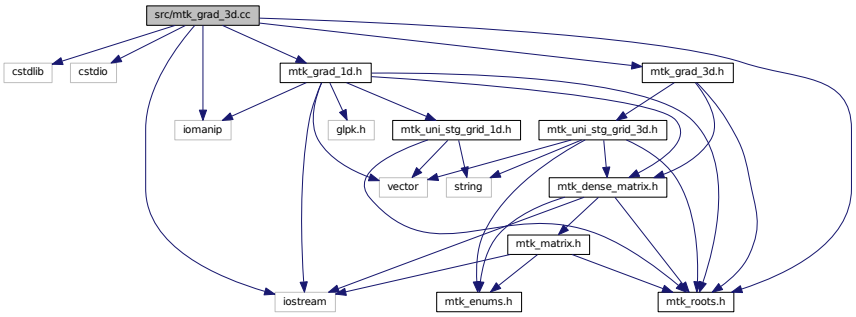
```
00100   auto west = grid.west_bndy();
00101   auto east = grid.east_bndy();
00102   auto south = grid.south_bndy();
00103   auto north = grid.east_bndy();
00104
00105   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00106   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00107
00108   mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));
00109   mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00110
00111   bool padded{true};
00112   bool transpose{true};
00113
00114   mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00115   mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00116
00117   mtk::DenseMatrix gxy(mtk::DenseMatrix::Kron(tiy, Gx));
00118   mtk::DenseMatrix gyx(mtk::DenseMatrix::Kron(Gy, tix));
00119
00120   #if MTK_VERBOSE_LEVEL > 2
00121   std::cout << "Gx: " << mx << " by " << nx << std::endl;
00122   std::cout << "Transpose Iy: " << num_cells_y << " by " << ny  << std::endl;
00123   std::cout << "Gy: " << my << " by " << ny << std::endl;
00124   std::cout << "Transpose Ix: " << num_cells_x << " by " << nx  << std::endl;
00125   std::cout << "Grad 2D: " << mx*num_cells_y + my*num_cells_x << " by " <<
00126     nx*ny <<std::endl;
00127   #endif
00128
00129   mtk::DenseMatrix g2d(mx*num_cells_y + my*num_cells_x, nx*ny);
00130
00131   for(auto ii = 0; ii < nx*ny; ii++) {
00132     for(auto jj = 0; jj < mx*num_cells_y; jj++) {
00133       g2d.SetValue(jj,ii, gxy.GetValue(jj,ii));
00134     }
00135     for(auto kk = 0; kk < my*num_cells_x; kk++) {
00136       g2d.SetValue(kk + mx*num_cells_y, ii, gyx.GetValue(kk,ii));
00137     }
00138   }
00139
00140   gradient_ = g2d;
00141
00142   return info;
00143 }
00144
00145 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix() const {
00146
00147   return gradient_;
00148 }
```

18.101 src/mtk_grad_3d.cc File Reference

Implements the class Grad3D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_grad_1d.h"
#include "mtk_grad_3d.h"
```

Include dependency graph for mtk_grad_3d.cc:



18.101.1 Detailed Description

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

Author

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

Definition in file mtk_grad_3d.cc.

18.102 mtk_grad_3d.cc

```
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00017
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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00030
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```

```
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_3d.h"
00066
00067 mtk::Grad3D::Grad3D():
00068   order_accuracy_(),
00069   mimetic_threshold_() {}
00070
00071 mtk::Grad3D::Grad3D(const Grad3D &grad):
00072   order_accuracy_(grad.order_accuracy_),
00073   mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad3D::~Grad3D() {}
00076
00077 bool mtk::Grad3D::ConstructGrad3D(const
      mtk::UniStgGrid3D &grid,
00078                                   int order_accuracy,
00079                                   mtk::Real mimetic_threshold) {
00080
00081   int num_cells_x = grid.num_cells_x();
00082   int num_cells_y = grid.num_cells_y();
00083   int num_cells_z = grid.num_cells_z();
00084
00085   int mx = num_cells_x + 1;  // Gx vertical dimension.
00086   int nx = num_cells_x + 2;  // Gx horizontal dimension.
00087   int my = num_cells_y + 1;  // Gy vertical dimension.
00088   int ny = num_cells_y + 2;  // Gy horizontal dimension.
00089   int mz = num_cells_z + 1;  // Gz vertical dimension.
00090   int nz = num_cells_z + 2;  // Gz horizontal dimension.
00091
00092   mtk::Grad1D grad;
00093
00094   bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00095
00096   #ifdef MTK_PERFORM_PREVENTIONS
00097   if (!info) {
00098     std::cerr << "Mimetic grad could not be built." << std::endl;
00099     return info;
00100   }
00101   #endif
00102
00103   auto west = grid.west_bndy();
00104   auto east = grid.east_bndy();
00105   auto south = grid.south_bndy();
00106   auto north = grid.east_bndy();
00107   auto bottom = grid.bottom_bndy();
00108   auto top = grid.top_bndy();
00109
00110   mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00111   mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00112   mtk::UniStgGrid1D grid_z(bottom, top, num_cells_z);
00113
00114   mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));
00115   mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00116   mtk::DenseMatrix Gz(grad.ReturnAsDenseMatrix(grid_z));
00117
00118   bool padded{true};
00119   bool transpose{true};
00120
00121   mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00122   mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00123   mtk::DenseMatrix tiz(num_cells_z, padded, transpose);
```

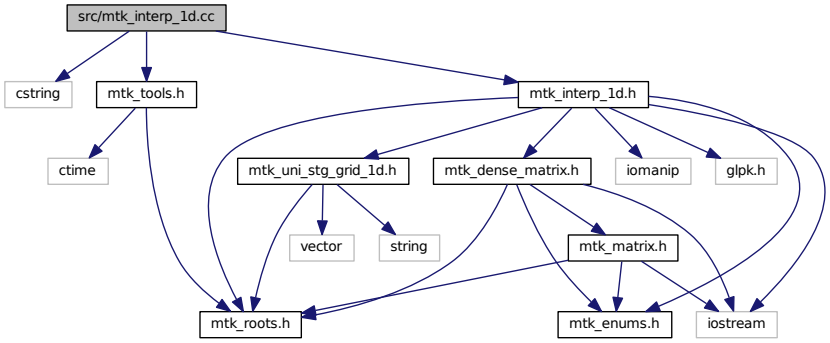
```
00124
00126
00127   mtk::DenseMatrix aux1(mtk::DenseMatrix::Kron(tiz, tiy));
00128   mtk::DenseMatrix gx(mtk::DenseMatrix::Kron(aux1, Gx));
00129
00131
00132   mtk::DenseMatrix aux2(mtk::DenseMatrix::Kron(tiz, Gy));
00133   mtk::DenseMatrix gy(mtk::DenseMatrix::Kron(aux2, tix));
00134
00136
00137   mtk::DenseMatrix aux3(mtk::DenseMatrix::Kron(Gz, tiy));
00138   mtk::DenseMatrix gz(mtk::DenseMatrix::Kron(aux3, tix));
00139
00140   #if MTK_VERBOSE_LEVEL > 2
00141   std::cout << "Gx: " << mx << " by " << nx << std::endl;
00142   std::cout << "Transpose Ix: " << num_cells_x << " by " << nx  << std::endl;
00143   std::cout << "Gy: " << my << " by " << ny << std::endl;
00144   std::cout << "Transpose Iy: " << num_cells_y << " by " << ny  << std::endl;
00145   std::cout << "Gz: " << mz << " by " << nz << std::endl;
00146   std::cout << "Transpose Iz: " << num_cells_z << " by " << nz  << std::endl;
00147   #endif
00148
00150
00151   int total_rows{mx*num_cells_y*num_cells_z +
00152                  num_cells_x*my*num_cells_z +
00153                  num_cells_x*num_cells_y*mz};
00154   int total_cols{nx*ny*nz};
00155
00156   #if MTK_VERBOSE_LEVEL > 2
00157   std::cout << "Grad 3D: " << total_rows << " by " << total_cols << std::endl;
00158   #endif
00159
00160   mtk::DenseMatrix g3d(total_rows, total_cols);
00161
00162   for(auto ii = 0; ii < total_cols; ii++) {
00163     for(auto jj = 0; jj < mx*num_cells_y*num_cells_z; jj++) {
00164       g3d.SetValue(jj,ii, gx.GetValue(jj,ii));
00165     }
00166
00167     int offset = mx*num_cells_y*num_cells_z;
00168
00169     for(auto kk = 0; kk < num_cells_x*my*num_cells_z; kk++) {
00170       g3d.SetValue(kk + offset, ii, gy.GetValue(kk,ii));
00171     }
00172
00173     offset += num_cells_x*my*num_cells_z;
00174
00175     for(auto ll = 0; ll < num_cells_x*num_cells_y*mz; ll++) {
00176       g3d.SetValue(ll + offset, ii, gz.GetValue(ll,ii));
00177     }
00178   }
00179
00180   gradient_ = g3d;
00181
00182   return info;
00183 }
00184
00185 mtk::DenseMatrix mtk::Grad3D::ReturnAsDenseMatrix() const {
00186
00187   return gradient_;
00188 }
```

18.103 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)

18.103.1 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.

18.104 mtk_interp_1d.cc

```
00001
00012 /*
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00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
```

```
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
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00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #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::DirInterp::SCALAR_TO_VECTOR),
00082   order_accuracy_(mtk::kDefaultOrderAccuracy),
00083   coeffs_interior_(nullptr) {}
00084
00085 mtk::Interp1D::Interp1D(const Interp1D &interp):
00086   dir_interp_(interp.dir_interp_),
00087   order_accuracy_(interp.order_accuracy_),
00088   coeffs_interior_(interp.coeffs_interior_) {}
00089
00090 mtk::Interp1D::~Interp1D() {
00091
00092   delete[] coeffs_interior_;
00093   coeffs_interior_ = nullptr;
00094 }
00095
00096 bool mtk::Interp1D::ConstructInterp1D(int order_accuracy,
      mtk::DirInterp dir) {
00097
00098   #if MTK_PERFORM_PREVENTIONS
00099   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00100   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00101   mtk::Tools::Prevent(dir < mtk::DirInterp::SCALAR_TO_VECTOR
       &&
00102                       dir > mtk::DirInterp::VECTOR_TO_SCALAR,
00103                       __FILE__, __LINE__, __func__);
00104   #endif
00105
```

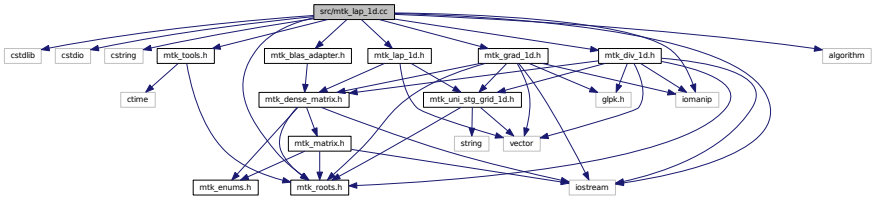
```
00106   #if MTK_VERBOSE_LEVEL > 2
00107   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00108   #endif
00109
00110   order_accuracy_ = order_accuracy;
00111
00113
00114   try {
00115     coeffs_interior_ = new mtk::Real[order_accuracy_];
00116   } catch (std::bad_alloc &memory_allocation_exception) {
00117     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00118       std::endl;
00119     std::cerr << memory_allocation_exception.what() << std::endl;
00120   }
00121   memset(coeffs_interior_,
00122          mtk::kZero,
00123          sizeof(coeffs_interior_[0])*order_accuracy_);
00124
00125   for (int ii = 0; ii < order_accuracy_; ++ii) {
00126     coeffs_interior_[ii] = mtk::kOne;
00127   }
00128
00129   return true;
00130 }
00131
00132 mtk::Real *mtk::Interp1D::coeffs_interior() const {
00133
00134   return coeffs_interior_;
00135 }
00136
00137 mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix(
00138   const UniStgGrid1D &grid) const {
00139
00140   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00141
00142   #if MTK_PERFORM_PREVENTIONS
00143   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00144   #endif
00145
00146   int gg_num_rows{};  // Number of rows.
00147   int gg_num_cols{};  // Number of columns.
00148
00149   if (dir_interp_ == mtk::DirInterp::SCALAR_TO_VECTOR) {
00150     gg_num_rows = nn + 1;
00151     gg_num_cols = nn + 2;
00152   } else {
00153     gg_num_rows = nn + 2;
00154     gg_num_cols = nn + 1;
00155   }
00156
00157   // Output matrix featuring sizes for gradient operators.
00158
00159   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00160
00162
00163   out.SetValue(0, 0, mtk::kOne);
00164
00166
00167   for (auto ii = 1; ii < gg_num_rows - 1; ++ii) {
00168     for(auto jj = ii ; jj < order_accuracy_ + ii; ++jj) {
00169       out.SetValue(ii, jj, mtk::kOne/order_accuracy_);
00170     }
00171   }
00172
00174
00175   out.SetValue(gg_num_rows - 1, gg_num_cols - 1, mtk::kOne);
00176
00177   return out;
00178 }
```

18.105 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 <algorithm>
#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)

18.105.1 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.

18.106 mtk_lap_1d.cc

```
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00011 /*
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00014
00015 Redistribution and use in source and binary forms, with or without modification,
```

```
00016 are permitted provided that the following conditions are met:
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00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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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 <algorithm>
00065
00066 #include "mtk_roots.h"
00067 #include "mtk_tools.h"
00068 #include "mtk_blas_adapter.h"
00069 #include "mtk_grad_1d.h"
00070 #include "mtk_div_1d.h"
00071 #include "mtk_lap_1d.h"
00072
00073 namespace mtk {
00074
00075 std::ostream& operator <<(std::ostream &stream, mtk::Lap1D &in) {
00076
00077   int output_precision{4};
00078   int output_width{8};
00079
00081
00082   stream << "Order of accuracy: " << in.laplacian_[0] << std::endl;
00083
00085
00086   stream << "Interior stencil: " << std::endl;
00087   for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00088     stream << std::setprecision(output_precision) << std::setw(output_width) <<
00089       in.laplacian_[ii] << ' ';
00090   }
00091   stream << std::endl;
00092
00094
00095   auto offset = 1 + (2*in.order_accuracy_ - 1);
00096
00097   for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00098     stream << "Boundary row " << ii + 1 << ":" << std::endl;
00099     for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
```

```
00100       stream << std::setprecision(output_precision) <<
00101         std::setw(output_width) <<
00102           in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj] << ' ';
00103     }
00104     stream << std::endl;
00105     stream << "Sum of elements in boundary row " << ii + 1 << ": " <<
00106       in.sums_rows_mim_bndy_[ii];
00107     stream << std::endl;
00108   }
00109
00110   return stream;
00111 }
00112 }
00113
00114 mtk::Lap1D::Lap1D():
00115   order_accuracy_(mtk::kDefaultOrderAccuracy),
00116   laplacian_length_(),
00117   delta_(mtk::kZero),
00118   mimetic_threshold_(mtk::kDefaultMimeticThreshold),
00119   mimetic_measure_(mtk::kZero),
00120   sums_rows_mim_bndy_() {}
00121
00122 mtk::Lap1D::Lap1D(const Lap1D &lap):
00123   order_accuracy_(lap.order_accuracy_),
00124   laplacian_length_(lap.laplacian_length_),
00125   delta_(lap.delta_),
00126   mimetic_threshold_(lap.mimetic_threshold_),
00127   mimetic_measure_(lap.mimetic_measure_),
00128   sums_rows_mim_bndy_(lap.sums_rows_mim_bndy_) {}
00129
00130 mtk::Lap1D::~Lap1D() {
00131
00132   delete [] laplacian_;
00133   laplacian_ = nullptr;
00134 }
00135
00136 int mtk::Lap1D::order_accuracy() const {
00137
00138   return order_accuracy_;
00139 }
00140
00141 mtk::Real mtk::Lap1D::mimetic_threshold() const {
00142
00143   return mimetic_threshold_;
00144 }
00145
00146 mtk::Real mtk::Lap1D::delta() const {
00147
00148   return delta_;
00149 }
00150
00151 bool mtk::Lap1D::ConstructLap1D(int order_accuracy,
00152                                 mtk::Real mimetic_threshold) {
00153
00154   #ifdef MTK_PERFORM_PREVENTIONS
00155   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00156   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00157   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00158                       __FILE__, __LINE__, __func__);
00159
00160   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00161     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00162   }
00163
00164   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00165   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00166   #endif
00167
00168   order_accuracy_ = order_accuracy;
00169   mimetic_threshold_ = mimetic_threshold;
00170
00172   mtk::Grad1D grad; // Mimetic gradient.
00173
00174   bool info = grad.ConstructGrad1D(order_accuracy_, mimetic_threshold_);
00175
00176   #ifdef MTK_PERFORM_PREVENTIONS
00177   if (!info) {
00178     std::cerr << "Mimetic grad could not be built." << std::endl;
00179     return false;
00180   }
00181   #endif
```

```
00182
00184
00185   mtk::Div1D div; // Mimetic divergence.
00186
00187   info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00188
00189   #ifdef MTK_PERFORM_PREVENTIONS
00190   if (!info) {
00191     std::cerr << "Mimetic div could not be built." << std::endl;
00192     return false;
00193   }
00194   #endif
00195
00197
00198   // Since these are mimetic operator, we must multiply the matrices arising
00199   // from both the divergence and the Laplacian, in order to get the
00200   // approximating coefficients for the Laplacian operator.
00201
00202   // However, we must choose a grid that implied a step size of 1, so to get
00203   // the approximating coefficients, without being affected from the
00204   // normalization with respect to the grid (dimensionless).
00205
00206   // Also, the grid must be of the minimum size to support the requested order
00207   // of accuracy. We must please the divergence for this!
00208
00209   mtk::UniStgGrid1D aux(mtk::kZero,
00210                         (mtk::Real) 3*order_accuracy_ - 1,
00211                         3*order_accuracy_ - 1);
00212
00213   #if MTK_VERBOSE_LEVEL > 2
00214   std::cout << "aux =" << std::endl;
00215   std::cout << aux << std::endl;
00216   std::cout << "aux.delta_x() = " << aux.delta_x() << std::endl;
00217   std::cout << std::endl;
00218   #endif
00219
00220   mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00221
00222   #if MTK_VERBOSE_LEVEL > 4
00223   std::cout << "grad_m =" << std::endl;
00224   std::cout << grad_m << std::endl;
00225   #endif
00226
00227   mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00228
00229   #if MTK_VERBOSE_LEVEL > 4
00230   std::cout << "div_m =" << std::endl;
00231   std::cout << div_m << std::endl;
00232   #endif
00233
00237
00238   mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00239
00240   lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00241
00242   #if MTK_VERBOSE_LEVEL > 4
00243   std::cout << "lap =" << std::endl;
00244   std::cout << lap << std::endl;
00245   #endif
00246
00248
00250
00251   // The output array will have this form:
00252   // 1. The first entry of the array will contain the used order kk.
00253   // 2. The second entry of the array will contain the collection of
00254   // approximating coefficients for the interior of the grid.
00255   // 3. The next entries will contain the collections of approximating
00256   // coefficients for the west boundary of the grid.
00257
00258   laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00259     (order_accuracy_ - 1)*(2*order_accuracy_);
00260
00261   #if MTK_VERBOSE_LEVEL > 2
00262   std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00263   std::cout << std::endl;
00264   #endif
00265
00266   try {
00267     laplacian_ = new mtk::Real[laplacian_length_];
00268   } catch (std::bad_alloc &memory_allocation_exception) {
00269     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
```

```
00270       std::endl;
00271     std::cerr << memory_allocation_exception.what() << std::endl;
00272   }
00273   memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00274
00276
00277   laplacian_[0] = order_accuracy_;
00278
00281
00282   for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00283     laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00284   }
00285
00287
00288   auto offset = 1 + (2*order_accuracy_ - 1);
00289
00290   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00291     sums_rows_mim_bndy_.push_back(mtk::kZero);
00292     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00293       register mtk::Real aux{lap.GetValue(1 + ii,jj)};
00294       laplacian_[offset + ii*(2*order_accuracy_) + jj] = aux;
00295       sums_rows_mim_bndy_[ii] += aux;
00296     }
00297   }
00298
00299     mimetic_measure_ = *std::max_element(sums_rows_mim_bndy_.begin(),
00300                                          sums_rows_mim_bndy_.end());
00301
00302   delta_ = mtk::kZero;
00303
00304   return true;
00305 }
00306
00307 std::vector<mtk::Real> mtk::Lap1D::sums_rows_mim_bndy() const {
00308
00309   return sums_rows_mim_bndy_;
00310 }
00311
00312 mtk::Real mtk::Lap1D::mimetic_measure() const {
00313
00314   return mimetic_measure_;
00315 }
00316
00317 mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix(
00318   const UniStgGrid1D &grid) const {
00319
00320   int nn{grid.num_cells_x()};  // Number of cells on the grid.
00321
00322   #ifdef MTK_PERFORM_PREVENTIONS
00323   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00324   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00325   #endif
00326
00327   mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00328
00329   delta_ = grid.delta_x();
00330
00331   mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
      dx^2.
00332
00334
00335   auto offset = (1 + 2*order_accuracy_ - 1);
00336
00337   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00338     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00339       lap.SetValue(1 + ii,
00340                    jj,
00341                    idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00342     }
00343   }
00344
00346
00347   offset = 1 + (order_accuracy_ - 1);
00348
00349   int kk{1};
00350   for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00351     int mm{1};
00352     for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00353       lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00354       mm = mm + 1;
00355     }
```

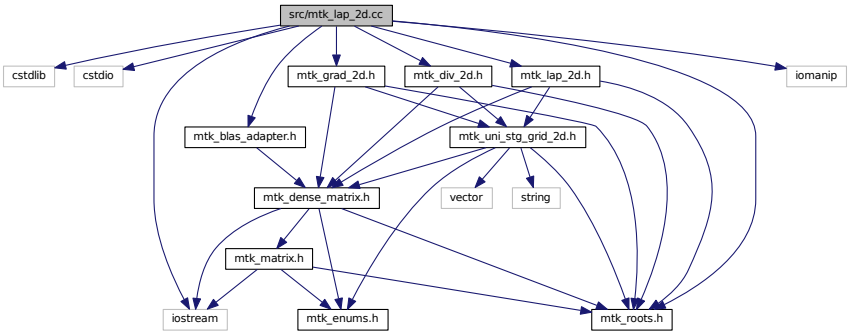
```
00356     kk = kk + 1;
00357   }
00358
00360
00361   offset = (1 + 2*order_accuracy_ - 1);
00362
00363   auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00364
00365   auto ll = 1;
00366   auto rr = 1;
00367   for (auto ii = nn; ii > aux - 1; --ii) {
00368     auto cc = 0;
00369     for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00370       lap.SetValue(ii, jj, lap.GetValue(rr,cc));
00371       ++ll;
00372       ++cc;
00373     }
00374     rr++;
00375   }
00376
00383
00384   return lap;
00385 }
00386
00387 const mtk::Real* mtk::Lap1D::data(const UniStgGrid1D &grid) const {
00388
00389   mtk::DenseMatrix tmp;
00390
00391   tmp = ReturnAsDenseMatrix(grid);
00392
00393   return tmp.data();
00394 }
```

18.107 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:



18.107.1 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.

18.108 mtk_lap_2d.cc

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
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00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_blas_adapter.h"
00065 #include "mtk_grad_2d.h"
00066 #include "mtk_div_2d.h"
00067 #include "mtk_lap_2d.h"
00068
00069 mtk::Lap2D::Lap2D(): order_accuracy_(), mimetic_threshold_() {}
```

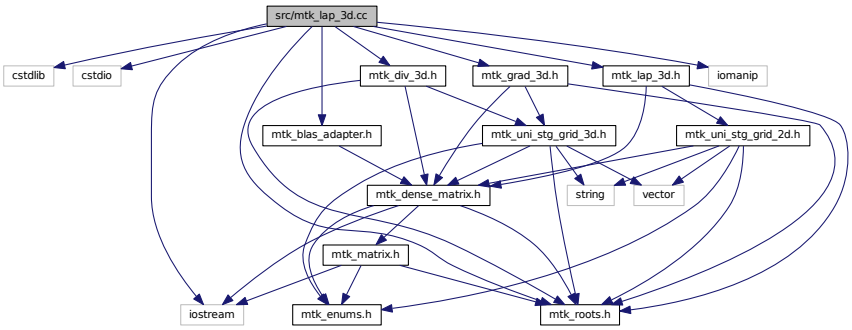
```
00070
00071 mtk::Lap2D::Lap2D(const Lap2D &lap):
00072   order_accuracy_(lap.order_accuracy_),
00073   mimetic_threshold_(lap.mimetic_threshold_) {}
00074
00075 mtk::Lap2D::~Lap2D() {}
00076
00077 bool mtk::Lap2D::ConstructLap2D(const
      mtk::UniStgGrid2D &grid,
00078                                 int order_accuracy,
00079                                 mtk::Real mimetic_threshold) {
00080
00081   mtk::Grad2D gg;
00082   mtk::Div2D dd;
00083
00084   bool info{gg.ConstructGrad2D(grid, order_accuracy, mimetic_threshold)};
00085
00086   #ifdef MTK_PERFORM_PREVENTIONS
00087   if (!info) {
00088     std::cerr << "Mimetic lap could not be built." << std::endl;
00089     return info;
00090   }
00091   #endif
00092
00093   info = dd.ConstructDiv2D(grid, order_accuracy, mimetic_threshold);
00094
00095   #ifdef MTK_PERFORM_PREVENTIONS
00096   if (!info) {
00097     std::cerr << "Mimetic div could not be built." << std::endl;
00098     return info;
00099   }
00100   #endif
00101
00102   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00103   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00104
00105   laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00106
00107   return info;
00108 }
00109
00110 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix() const {
00111
00112   return laplacian_;
00113 }
00114
00115 mtk::Real *mtk::Lap2D::data() const {
00116
00117   return laplacian_.data();
00118 }
```

18.109 src/mtk_lap_3d.cc File Reference

Includes the implementation of the class Lap3D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_3d.h"
#include "mtk_div_3d.h"
#include "mtk_lap_3d.h"
```

Include dependency graph for mtk_lap_3d.cc:



18.109.1 Detailed Description

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

Author

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

Definition in file mtk_lap_3d.cc.

18.110 mtk_lap_3d.cc

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

```
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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_3d.h"
00066 #include "mtk_div_3d.h"
00067 #include "mtk_lap_3d.h"
00068
00069 mtk::UniStgGrid3D mtk::Lap3D::operator*(const
      mtk::UniStgGrid3D &grid) const {
00070
00071   mtk::UniStgGrid3D out;
00072
00073   return out;
00074 }
00075
00076 mtk::Lap3D::Lap3D(): order_accuracy_(), mimetic_threshold_() {}
00077
00078 mtk::Lap3D::Lap3D(const Lap3D &lap):
00079   order_accuracy_(lap.order_accuracy_),
00080   mimetic_threshold_(lap.mimetic_threshold_) {}
00081
00082 mtk::Lap3D::~Lap3D() {}
00083
00084 bool mtk::Lap3D::ConstructLap3D(const
      mtk::UniStgGrid3D &grid,
00085                                 int order_accuracy,
00086                                 mtk::Real mimetic_threshold) {
00087
00088   mtk::Grad3D gg;
00089   mtk::Div3D dd;
00090
00091   bool info{gg.ConstructGrad3D(grid, order_accuracy, mimetic_threshold)};
00092
00093   #ifdef MTK_PERFORM_PREVENTIONS
00094   if (!info) {
00095     std::cerr << "Mimetic lap could not be built." << std::endl;
00096     return info;
00097   }
00098   #endif
00099
00100   info = dd.ConstructDiv3D(grid, order_accuracy, mimetic_threshold);
00101
00102   #ifdef MTK_PERFORM_PREVENTIONS
00103   if (!info) {
00104     std::cerr << "Mimetic div could not be built." << std::endl;
00105     return info;
00106   }
00107   #endif
00108
00109   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00110   mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00111
00112   laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00113
00114   return info;
00115 }
00116
00117 mtk::DenseMatrix mtk::Lap3D::ReturnAsDenseMatrix() const {
00118
00119   return laplacian_;
00120 }
00121
```

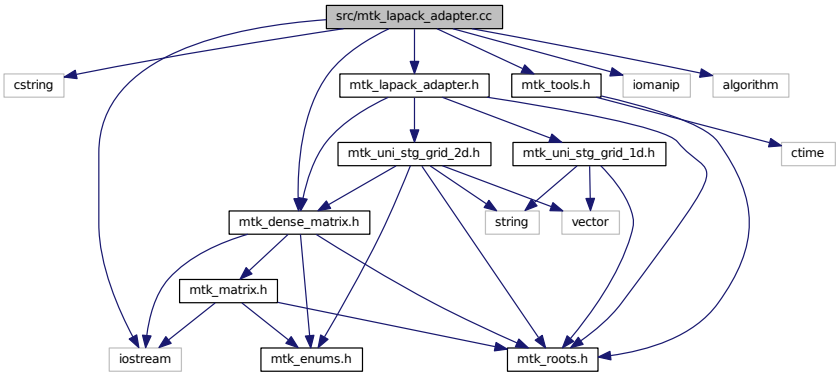
```
00122 mtk::Real *mtk::Lap3D::data() const {
00123
00124   return laplacian_.data();
00125 }
```

18.111 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.

18.111.1 Detailed Description

Implementation of a class that contains a collection of static member functions, 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.

18.112 mtk_lapack_adapter.cc

```
00001
00022 /*
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00030 and a copy of the modified files should be reported once modifications are
00031 completed, unless these modifications are made through the project's GitHub
00032 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00033 should be developed and included in any deliverable.
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00036 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

```
00064 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
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00066 */
00067
00068 #include <cstring>
00069
00070 #include <iostream>
00071 #include <iomanip>
00072
00073 #include <algorithm>
00074
00075 #include "mtk_tools.h"
00076 #include "mtk_dense_matrix.h"
00077 #include "mtk_lapack_adapter.h"
00078
00079 namespace mtk {
00080
00081 extern "C" {
00082
00083 #ifdef MTK_PRECISION_DOUBLE
00084
00103 void dgesv_(int* n,
00104             int* nrhs,
00105             Real* a,
00106             int* lda,
00107             int* ipiv,
00108             Real* b,
00109             int* ldb,
00110             int* info);
00111 #else
00112
00131 void sgesv_(int* n,
00132             int* nrhs,
00133             Real* a,
00134             int* lda,
00135             int* ipiv,
00136             Real* b,
00137             int* ldb,
00138             int* info);
00139 #endif
00140
00141 #ifdef MTK_PRECISION_DOUBLE
00142
00185 void dgels_(char* trans,
00186             int* m,
00187             int* n,
00188             int* nrhs,
00189             Real* a,
00190             int* lda,
00191             Real* b,
00192             int* ldb,
00193             Real* work,
00194             int* lwork,
00195             int* info);
00196 #else
00197
00240 void sgels_(char* trans,
00241             int* m,
00242             int* n,
00243             int* nrhs,
00244             Real* a,
00245             int* lda,
00246             Real* b,
00247             int* ldb,
00248             Real* work,
00249             int* lwork,
00250             int* info);
00251 #endif
00252
00253 #ifdef MTK_PRECISION_DOUBLE
00254
00283 void dgeqrf_(int *m,
00284              int *n,
00285              Real *a,
00286              int *lda,
00287              Real *tau,
00288              Real *work,
00289              int *lwork,
00290              int *info);
00291 #else
00292
```

```
00321 void sgeqrf_(int *m,
00322              int *n,
00323              Real *a,
00324              int *lda,
00325              Real *tau,
00326              Real *work,
00327              int *lwork,
00328              int *info);
00329 #endif
00330
00331 #ifdef MTK_PRECISION_DOUBLE
00332
00366 void dormqr_(char *side,
00367              char *trans,
00368              int *m,
00369              int *n,
00370              int *k,
00371              Real *a,
00372              int *lda,
00373              Real *tau,
00374              Real *c,
00375              int *ldc,
00376              Real *work,
00377              int *lwork,
00378              int *info);
00379 #else
00380
00414 void sormqr_(char *side,
00415              char *trans,
00416              int *m,
00417              int *n,
00418              int *k,
00419              Real *a,
00420              int *lda,
00421              Real *tau,
00422              Real *c,
00423              int *ldc,
00424              Real *work,
00425              int *lwork,
00426              int *info);
00427 #endif
00428 }
00429 }
00430
00431 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00432                                          mtk::Real *rhs) {
00433
00434   #ifdef MTK_PERFORM_PREVENTIONS
00435   mtk::Tools::Prevent(rhs == nullptr, __FILE__, __LINE__, __func__);
00436   #endif
00437
00438   int *ipiv{};                // Array for pivoting information.
00439   int nrhs{1};                // Number of right-hand sides.
00440   int info{};                 // Status of the solution.
00441   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00442
00443   try {
00444     ipiv = new int[mm_rank];
00445   } catch (std::bad_alloc &memory_allocation_exception) {
00446     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00447       std::endl;
00448     std::cerr << memory_allocation_exception.what() << std::endl;
00449   }
00450   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00451
00452   int ldbb = mm_rank;
00453   int mm_ld = mm_rank;
00454
00455   #ifdef MTK_PRECISION_DOUBLE
00456   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00457   #else
00458   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00459   #endif
00460
00461   delete [] ipiv;
00462
00463   return info;
00464 }
00465
00466 int mtk::LAPACKAdapter::SolveDenseSystem(
```

```
      mtk::DenseMatrix &mm,
00467                                         mtk::DenseMatrix &bb) {
00468
00469   int nrhs{bb.num_rows()};  // Number of right-hand sides.
00470
00471   #ifdef MTK_PERFORM_PREVENTIONS
00472   mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00473   #endif
00474
00475   int *ipiv{};                // Array for pivoting information.
00476   int info{};                 // Status of the solution.
00477   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00478
00479   try {
00480     ipiv = new int[mm_rank];
00481   } catch (std::bad_alloc &memory_allocation_exception) {
00482     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00483       std::endl;
00484     std::cerr << memory_allocation_exception.what() << std::endl;
00485   }
00486   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00487
00488   int ldbb = mm_rank;
00489   int mm_ld = mm_rank;
00490
00491   #ifdef MTK_PRECISION_DOUBLE
00492   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00493   #else
00494   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00495   #endif
00496
00497   delete [] ipiv;
00498
00499   // After output, the data in the matrix will be column-major ordered.
00500
00501   bb.SetOrdering(mtk::MatrixOrdering::COL_MAJOR);
00502
00503   #if MTK_VERBOSE_LEVEL > 12
00504   std::cout << "bb_col_maj_ord =" << std::endl;
00505   std::cout << bb << std::endl;
00506   #endif
00507
00508   bb.OrderRowMajor();
00509
00510   #if MTK_VERBOSE_LEVEL > 12
00511   std::cout << "bb_row_maj_ord =" << std::endl;
00512   std::cout << bb << std::endl;
00513   #endif
00514
00515   return info;
00516 }
00517
00518 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00519                                         mtk::UniStgGrid1D &rhs) {
00520
00521   int nrhs{1};  // Number of right-hand sides.
00522
00523   int *ipiv{};                // Array for pivoting information.
00524   int info{};                 // Status of the solution.
00525   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00526
00527   try {
00528     ipiv = new int[mm_rank];
00529   } catch (std::bad_alloc &memory_allocation_exception) {
00530     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00531       std::endl;
00532     std::cerr << memory_allocation_exception.what() << std::endl;
00533   }
00534   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00535
00536   int ldbb = mm_rank;
00537   int mm_ld = mm_rank;
00538
00539   mm.OrderColMajor();
00540
00541   #ifdef MTK_PRECISION_DOUBLE
00542   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00543          rhs.discrete_field(), &ldbb, &info);
00544   #else
00545   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
```

```
00546           rhs.discrete_field(), &ldbb, &info);
00547   #endif
00548
00549   mm.OrderRowMajor();
00550
00551   delete [] ipiv;
00552
00553   return info;
00554 }
00555
00556 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00557                                          mtk::UniStgGrid2D &rhs) {
00558
00559   int nrhs{1};  // Number of right-hand sides.
00560
00561   int *ipiv{};               // Array for pivoting information.
00562   int info{};                // Status of the solution.
00563   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00564
00565   try {
00566     ipiv = new int[mm_rank];
00567   } catch (std::bad_alloc &memory_allocation_exception) {
00568     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00569       std::endl;
00570     std::cerr << memory_allocation_exception.what() << std::endl;
00571   }
00572   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00573
00574   int ldbb = mm_rank;
00575   int mm_ld = mm_rank;
00576
00577   mm.OrderColMajor();
00578
00579   #ifdef MTK_PRECISION_DOUBLE
00580   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00581           rhs.discrete_field(), &ldbb, &info);
00582   #else
00583   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00584           rhs.discrete_field(), &ldbb, &info);
00585   #endif
00586
00587   mm.OrderRowMajor();
00588
00589   delete [] ipiv;
00590
00591   return info;
00592 }
00593
00594 mtk::DenseMatrix mtk::LAPACKAdapter::QRFactorDenseMatrix
      (mtk::DenseMatrix &aa) {
00595
00596   mtk::Real *work{}; // Working array.
00597   mtk::Real *tau{};  // Array for the Householder scalars.
00598
00599   // Prepare to factorize: allocate and inquire for the value of lwork.
00600   try {
00601     work = new mtk::Real[1];
00602   } catch (std::bad_alloc &memory_allocation_exception) {
00603     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00604       std::endl;
00605     std::cerr << memory_allocation_exception.what() << std::endl;
00606   }
00607   memset(work, mtk::kZero, sizeof(aa.data()[0])*1);
00608
00609   int lwork{-1};
00610   int info{};
00611
00612   int aa_num_cols = aa.num_cols();
00613   int aaT_num_rows = aa.num_cols();
00614   int aaT_num_cols = aa.num_rows();
00615
00616   #if MTK_VERBOSE_LEVEL > 12
00617   std::cout << "Input matrix BEFORE QR factorization:" << std::endl;
00618   std::cout << aa << std::endl;
00619   #endif
00620
00621   #ifdef MTK_PRECISION_DOUBLE
00622   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00623           tau,
00624           work, &lwork, &info);
```

```
00625   #else
00626   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00627           tau,
00628           work, &lwork, &info);
00629   #endif
00630
00631   if (info == 0) {
00632     lwork = (int) work[0];
00633   } else {
00634     std::cerr << "Could not get value for lwork on line " << __LINE__ - 5 <<
00635       std::endl;
00636     std::cerr << "Exiting..." << std::endl;
00637   }
00638
00639   #if MTK_VERBOSE_LEVEL > 10
00640   std::cout << "lwork = " << std::endl << std::setw(12) << lwork << std::endl
00641     << std::endl;
00642   #endif
00643
00644   delete [] work;
00645   work = nullptr;
00646
00647   // Once we know lwork, we can actually invoke the factorization:
00648   try {
00649     work = new mtk::Real [lwork];
00650   } catch (std::bad_alloc &memory_allocation_exception) {
00651     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00652       std::endl;
00653     std::cerr << memory_allocation_exception.what() << std::endl;
00654   }
00655   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00656
00657   int ltau = std::min(aaT_num_rows,aaT_num_cols);
00658
00659   try {
00660     tau = new mtk::Real [ltau];
00661   } catch (std::bad_alloc &memory_allocation_exception) {
00662     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00663       std::endl;
00664     std::cerr << memory_allocation_exception.what() << std::endl;
00665   }
00666   memset(tau, mtk::kZero, sizeof(0.0)*ltau);
00667
00668   #ifdef MTK_PRECISION_DOUBLE
00669   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00670           tau, work, &lwork, &info);
00671   #else
00672   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00673           tau, work, &lwork, &info);
00674   #endif
00675
00676   #ifdef MTK_PERFORM_PREVENTIONS
00677   if (!info) {
00678     std::cout << "QR factorization completed!" << std::endl << std::endl;
00679   } else {
00680     std::cerr << "Error solving system! info = " << info << std::endl;
00681     std::cerr << "Exiting..." << std::endl;
00682   }
00683   #endif
00684
00685   #if MTK_VERBOSE_LEVEL > 12
00686   std::cout << "Input matrix AFTER QR factorization:" << std::endl;
00687   std::cout << aa << std::endl;
00688   #endif
00689
00690   // We now generate the real matrix Q with orthonormal columns. This has to
00691   // be done separately since the actual output of dgeqrf_ (AA_) represents
00692   // the orthogonal matrix Q as a product of min(aa_num_rows, aa_num_cols)
00693   // elementary Householder reflectors. Notice that we must re-inquire the new
00694   // value for lwork that is used.
00695
00696   bool padded{false};
00697
00698   bool transpose{false};
00699
00700   mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00701
00702   #if MTK_VERBOSE_LEVEL > 12
00703   std::cout << "Initialized QQ_T: " << std::endl;
00704   std::cout << QQ_ << std::endl;
00705   #endif
```

```
00706
00707   // Assemble the QQ_ matrix:
00708   lwork = -1;
00709
00710   delete[] work;
00711   work = nullptr;
00712
00713   try {
00714     work = new mtk::Real[1];
00715   } catch (std::bad_alloc &memory_allocation_exception) {
00716     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00717       std::endl;
00718     std::cerr << memory_allocation_exception.what() <<
00719       std::endl;
00720   }
00721   memset(work, mtk::kZero, sizeof(work[0])*1);
00722
00723   char side_{'L'};
00724   char trans_{'N'};
00725
00726   int aux = QQ_.num_rows();
00727
00728   #ifdef MTK_PRECISION_DOUBLE
00729   dormqr_(&side_, &trans_,
00730           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00731           QQ_.data(), &aux, work, &lwork, &info);
00732   #else
00733   formqr_(&side_, &trans_,
00734           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00735           QQ_.data(), &aux, work, &lwork, &info);
00736   #endif
00737
00738   if (info == 0) {
00739     lwork = (int) work[0];
00740   } else {
00741     std::cerr << "Could not get lwork on line " << __LINE__ - 5 << std::endl;
00742     std::cerr << "Exiting..." << std::endl;
00743   }
00744
00745   #if MTK_VERBOSE_LEVEL > 10
00746   std::cout << "lwork = " << std::endl << std::setw(12) << lwork <<
00747     std::endl << std::endl;
00748   #endif
00749
00750   delete[] work;
00751   work = nullptr;
00752
00753   try {
00754     work = new mtk::Real[lwork];
00755   } catch (std::bad_alloc &memory_allocation_exception) {
00756     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00757       std::endl;
00758     std::cerr << memory_allocation_exception.what() << std::endl;
00759   }
00760   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00761
00762   #ifdef MTK_PRECISION_DOUBLE
00763   dormqr_(&side_, &trans_,
00764           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00765           QQ_.data(), &aux, work, &lwork, &info);
00766   #else
00767   formqr_(&side_, &trans_,
00768           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00769           QQ_.data(), &aux, work, &lwork, &info);
00770   #endif
00771
00772   #ifdef MTK_PERFORM_PREVENTIONS
00773   if (!info) {
00774     std::cout << "Q matrix successfully assembled!" << std::endl << std::endl;
00775   } else {
00776     std::cerr << "Something went wrong solving system! info = " << info <<
00777       std::endl;
00778     std::cerr << "Exiting..." << std::endl;
00779   }
00780   #endif
00781
00782   delete[] work;
00783   work = nullptr;
00784
00785   delete[] tau;
00786   tau = nullptr;
```

```
00787
00788   return QQ_;
00789 }
00790
00791 int mtk::LAPACKAdapter::SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00792                                                     mtk::Real *ob_,
00793                                                     int ob_ld_) {
00794
00795   // We first invoke the solver to query for the value of lwork. For this,
00796   // we must at least allocate enough space to allow access to WORK(1), or
00797   // work[0]:
00798
00799   // If LWORK = -1, then a workspace query is assumed; the routine only
00800   // calculates the optimal size of the WORK array, returns this value as
00801   // the first entry of the WORK array, and no error message related to
00802   // LWORK is issued by XERBLA.
00803
00804   mtk::Real *work{}; // Work array.
00805
00806   try {
00807     work = new mtk::Real[1];
00808   } catch (std::bad_alloc &memory_allocation_exception) {
00809     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00810       std::endl;
00811     std::cerr << memory_allocation_exception.what() << std::endl;
00812   }
00813   memset(work, mtk::kZero, sizeof(work[0])*1);
00814
00815   char trans_{'N'};
00816   int nrhs_{1};
00817   int info{0};
00818   int lwork{-1};
00819
00820   int AA_num_rows_  = aa.num_cols();
00821   int AA_num_cols_  = aa.num_rows();
00822   int AA_ld_ = std::max(1,aa.num_cols());
00823
00824   #ifdef MTK_PRECISION_DOUBLE
00825   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00826          ob_, &ob_ld_,
00827          work, &lwork, &info);
00828   #else
00829   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00830          ob_, &ob_ld_,
00831          work, &lwork, &info);
00832   #endif
00833
00834   if (info == 0) {
00835     lwork = (int) work[0];
00836   } else {
00837     std::cerr << "Could not get value for lwork on line " << __LINE__ - 2 <<
00838       std::endl;
00839     std::cerr << "Exiting..." << std::endl;
00840     return info;
00841   }
00842
00843   #if MTK_VERBOSE_LEVEL > 10
00844   std::cout << "lwork = " << std::endl << std::setw(12)<< lwork <<
00845     std::endl << std::endl;
00846   #endif
00847
00848   // We then use lwork's new value to create the work array:
00849   delete[] work;
00850   work = nullptr;
00851
00852   try {
00853     work = new mtk::Real[lwork];
00854   } catch (std::bad_alloc &memory_allocation_exception) {
00855     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00856     std::cerr << memory_allocation_exception.what() << std::endl;
00857   }
00858   memset(work, 0.0, sizeof(work[0])*lwork);
00859
00860   // We now invoke the solver again:
00861   #ifdef MTK_PRECISION_DOUBLE
00862   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00863          ob_, &ob_ld_,
00864          work, &lwork, &info);
00865   #else
00866   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
```

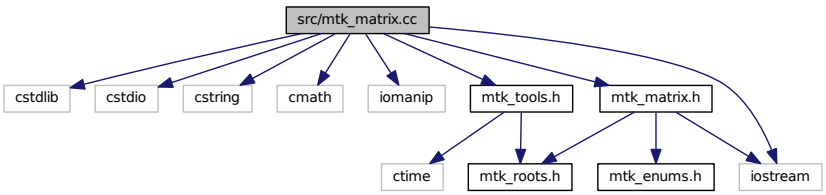
```
00867           ob_, &ob_ld_,
00868           work, &lwork, &info);
00869   #endif
00870
00871   delete [] work;
00872   work = nullptr;
00873
00874   return info;
00875 }
```

18.113 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:



18.113.1 Detailed Description

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

Author

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Definition in file mtk_matrix.cc.

18.114 mtk_matrix.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
```

```
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <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::MatrixStorage::DENSE),
00069   ordering_(mtk::MatrixOrdering::ROW_MAJOR),
00070   num_rows_(),
00071   num_cols_(),
00072   num_values_(),
00073   ld_(),
00074   num_zero_(),
00075   num_non_zero_(),
00076   num_null_(),
00077   num_non_null_(),
00078   kl_(),
00079   ku_(),
00080   bandwidth_(),
00081   abs_density_(),
00082   rel_density_(),
00083   abs_sparsity_(),
00084   rel_sparsity_() {}
00085
00086 mtk::Matrix::Matrix(const Matrix &in):
00087   storage_(in.storage_),
00088   ordering_(in.ordering_),
00089   num_rows_(in.num_rows_),
00090   num_cols_(in.num_cols_),
00091   num_values_(in.num_values_),
00092   ld_(in.ld_),
00093   num_zero_(in.num_zero_),
00094   num_non_zero_(in.num_non_zero_),
00095   num_null_(in.num_null_),
00096   num_non_null_(in.num_non_null_),
00097   kl_(in.kl_),
00098   ku_(in.ku_),
```

```
00099   bandwidth_(in.bandwidth_),
00100   abs_density_(in.abs_density_),
00101   rel_density_(in.rel_density_),
00102   abs_sparsity_(in.abs_sparsity_),
00103   rel_sparsity_(in.rel_sparsity_) {}
00104
00105 mtk::Matrix::~Matrix() noexcept {}
00106
00107 mtk::MatrixStorage mtk::Matrix::storage() const noexcept {
00108
00109   return storage_;
00110 }
00111
00112 mtk::MatrixOrdering mtk::Matrix::ordering() const noexcept {
00113
00114   return ordering_;
00115 }
00116
00117 int mtk::Matrix::num_rows() const noexcept {
00118
00119   return num_rows_;
00120 }
00121
00122 int mtk::Matrix::num_cols() const noexcept {
00123
00124   return num_cols_;
00125 }
00126
00127 int mtk::Matrix::num_values() const noexcept {
00128
00129   return num_values_;
00130 }
00131
00132 int mtk::Matrix::ld() const noexcept {
00133
00134   return ld_;
00135 }
00136
00137 int mtk::Matrix::num_zero() const noexcept {
00138
00139   return num_zero_;
00140 }
00141
00142 int mtk::Matrix::num_non_zero() const noexcept {
00143
00144   return num_non_zero_;
00145 }
00146
00147 int mtk::Matrix::num_null() const noexcept {
00148
00149   return num_null_;
00150 }
00151
00152 int mtk::Matrix::num_non_null() const noexcept {
00153
00154   return num_non_null_;
00155 }
00156
00157 int mtk::Matrix::kl() const noexcept {
00158
00159   return kl_;
00160 }
00161
00162 int mtk::Matrix::ku() const noexcept {
00163
00164   return ku_;
00165 }
00166
00167 int mtk::Matrix::bandwidth() const noexcept {
00168
00169   return bandwidth_;
00170 }
00171
00172 mtk::Real mtk::Matrix::rel_density() const noexcept {
00173
00174   return rel_density_;
00175 }
00176
00177 mtk::Real mtk::Matrix::abs_sparsity() const noexcept {
00178
00179   return abs_sparsity_;
```

```
00180 }
00181
00182 mtk::Real mtk::Matrix::rel_sparsity() const noexcept {
00183
00184   return rel_sparsity_;
00185 }
00186
00187 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss)
      noexcept {
00188
00189   #ifdef MTK_PERFORM_PREVENTIONS
00190   mtk::Tools::Prevent(!(ss == mtk::MatrixStorage::DENSE ||
00191                         ss == mtk::MatrixStorage::BANDED ||
00192                         ss == mtk::MatrixStorage::CRS),
00193                       __FILE__, __LINE__, __func__);
00194   #endif
00195
00196   storage_ = ss;
00197 }
00198
00199 void mtk::Matrix::set_ordering(const
      mtk::MatrixOrdering &oo) noexcept {
00200
00201   #ifdef MTK_PERFORM_PREVENTIONS
00202   bool aux{oo == mtk::MatrixOrdering::ROW_MAJOR ||
00203            oo == mtk::MatrixOrdering::COL_MAJOR};
00204   mtk::Tools::Prevent(!aux, __FILE__, __LINE__, __func__);
00205   #endif
00206
00207   ordering_ = oo;
00208
00209   ld_ = (ordering_ == mtk::MatrixOrdering::ROW_MAJOR)?
00210     std::max(1,num_cols_): std::max(1,num_rows_);
00211 }
00212
00213 void mtk::Matrix::set_num_rows(const int &in) noexcept {
00214
00215   #ifdef MTK_PERFORM_PREVENTIONS
00216   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00217   #endif
00218
00219   num_rows_ = in;
00220   num_values_ = num_rows_*num_cols_;
00221   ld_ = (ordering_ == mtk::MatrixOrdering::ROW_MAJOR)?
00222     std::max(1,num_cols_): std::max(1,num_rows_);
00223 }
00224
00225 void mtk::Matrix::set_num_cols(const int &in) noexcept {
00226
00227   #ifdef MTK_PERFORM_PREVENTIONS
00228   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00229   #endif
00230
00231   num_cols_ = in;
00232   num_values_ = num_rows_*num_cols_;
00233   ld_ = (ordering_ == mtk::MatrixOrdering::ROW_MAJOR)?
00234     std::max(1,num_cols_): std::max(1,num_rows_);
00235 }
00236
00237 void mtk::Matrix::set_num_zero(const int &in) noexcept {
00238
00239   #ifdef MTK_PERFORM_PREVENTIONS
00240   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00241   #endif
00242
00243   num_zero_ = in;
00244   num_non_zero_ = num_values_ - num_zero_;
00245
00247   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00248   rel_sparsity_ = 1.0 - rel_density_;
00249 }
00250
00251 void mtk::Matrix::set_num_null(const int &in) noexcept {
00252
00253   #ifdef MTK_PERFORM_PREVENTIONS
00254   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00255   #endif
00256
00257   num_null_ = in;
00258   num_non_null_ = num_values_ - num_null_;
00259
```

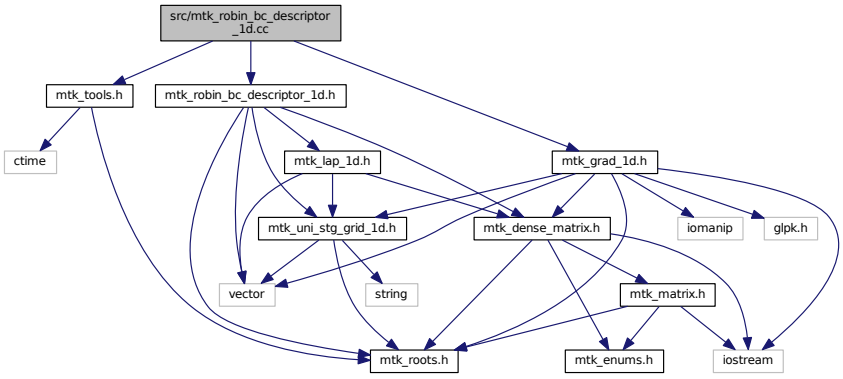
```
00261   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00262   abs_sparsity_ = 1.0 - abs_density_;
00263 }
00264
00265 void mtk::Matrix::IncreaseNumZero() noexcept {
00266
00268
00269   num_zero_++;
00270   num_non_zero_ = num_values_ - num_zero_;
00271   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00272   rel_sparsity_ = 1.0 - rel_density_;
00273 }
00274
00275 void mtk::Matrix::IncreaseNumNull() noexcept {
00276
00278
00279   num_null_++;
00280   num_non_null_ = num_values_ - num_null_;
00281   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00282   abs_sparsity_ = 1.0 - abs_density_;
00283 }
```

18.115 src/mtk_robin_bc_descriptor_1d.cc File Reference

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

```
#include "mtk_tools.h"
#include "mtk_grad_1d.h"
#include "mtk_robin_bc_descriptor_1d.h"
```

Include dependency graph for mtk_robin_bc_descriptor_1d.cc:



18.115.1 Detailed Description

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

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

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

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

equation of interest.

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

$$\delta_a(a,t)u(a,t) - \eta_a(a,t)u'(a,t) = \beta_a(a,t),$$

$$\delta_b(b,t)u(b,t) + \eta_b(b,t)u'(b,t) = \beta_b(b,t).$$

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west and east, in 1D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the condition in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Author

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

Definition in file mtk_robin_bc_descriptor_1d.cc.

18.116 mtk_robin_bc_descriptor_1d.cc

```
00001
00043 /*
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00045 University. All rights reserved.
00046
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00048 are permitted provided that the following conditions are met:
00049
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00051 and a copy of the modified files should be reported once modifications are
00052 completed, unless these modifications are made through the project's GitHub
00053 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00054 should be developed and included in any deliverable.
00055
00056 2. Redistributions of source code must be done through direct
00057 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00079 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00084 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00085 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
```

```
00086 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00087 */
00088
00089 #include "mtk_tools.h"
00090 #include "mtk_grad_1d.h"
00091 #include "mtk_robin_bc_descriptor_1d.h"
00092
00093 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D():
00094   highest_order_diff_west_(-1),
00095   highest_order_diff_east_(-1),
00096   west_condition_(nullptr),
00097   east_condition_(nullptr) {}
00098
00099 mtk::RobinBCDescriptor1D::RobinBCDescriptor1D(
00100     const mtk::RobinBCDescriptor1D &desc):
00101   highest_order_diff_west_(desc.highest_order_diff_west_),
00102   highest_order_diff_east_(desc.highest_order_diff_east_),
00103   west_condition_(desc.west_condition_),
00104   east_condition_(desc.east_condition_) {}
00105
00106 mtk::RobinBCDescriptor1D::~RobinBCDescriptor1D() noexcept {}
00107
00108 int mtk::RobinBCDescriptor1D::highest_order_diff_west()
     const noexcept {
00109
00110   return highest_order_diff_west_;
00111 }
00112
00113 int mtk::RobinBCDescriptor1D::highest_order_diff_east()
     const noexcept {
00114
00115   return highest_order_diff_east_;
00116 }
00117
00118 void mtk::RobinBCDescriptor1D::PushBackWestCoeff(
00119     mtk::CoefficientFunction0D cw) {
00120
00121   #ifdef MTK_PERFORM_PREVENTIONS
00122   mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00123   mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00124                       __FILE__, __LINE__, __func__);
00125   #endif
00126
00127   west_coefficients_.push_back(cw);
00128
00129   highest_order_diff_west_++;
00130 }
00131
00132 void mtk::RobinBCDescriptor1D::PushBackEastCoeff(
00133     mtk::CoefficientFunction0D ce) {
00134
00135   #ifdef MTK_PERFORM_PREVENTIONS
00136   mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00137   mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00138                       __FILE__, __LINE__, __func__);
00139   #endif
00140
00141   east_coefficients_.push_back(ce);
00142
00143   highest_order_diff_east_++;
00144 }
00145
00146 void mtk::RobinBCDescriptor1D::set_west_condition(
00147     mtk::Real (*west_condition)(const mtk::Real &tt)) noexcept {
00148
00149   #ifdef MTK_PERFORM_PREVENTIONS
00150   mtk::Tools::Prevent(west_condition == nullptr, __FILE__, __LINE__, __func__);
00151   #endif
00152
00153   west_condition_ = west_condition;
00154 }
00155
00156 void mtk::RobinBCDescriptor1D::set_east_condition(
00157     mtk::Real (*east_condition)(const mtk::Real &tt)) noexcept {
00158
00159   #ifdef MTK_PERFORM_PREVENTIONS
00160   mtk::Tools::Prevent(east_condition == nullptr, __FILE__, __LINE__, __func__);
00161   #endif
00162
00163   east_condition_ = east_condition;
00164 }
```

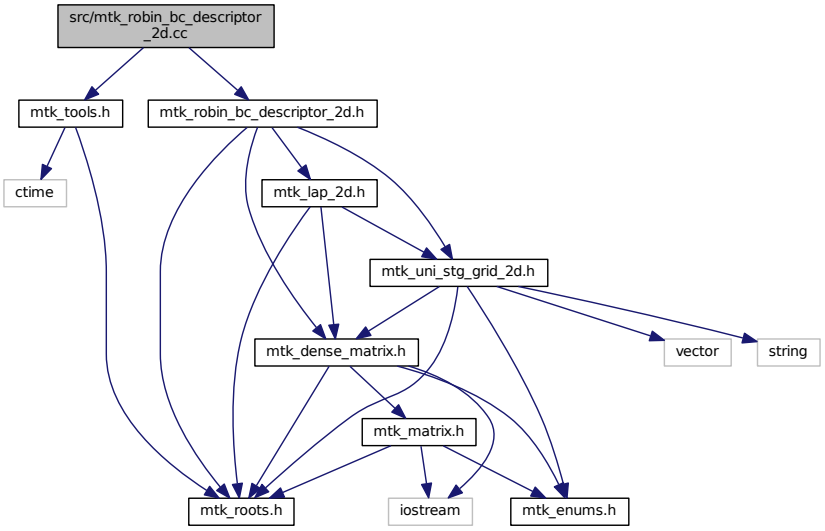
```
00165
00166 bool mtk::RobinBCDescriptor1D::ImposeOnLaplacianMatrix(
00167     const mtk::Lap1D &lap,
00168     mtk::DenseMatrix &matrix,
00169     const mtk::Real &time) const {
00170
00171   #ifdef MTK_PERFORM_PREVENTIONS
00172   mtk::Tools::Prevent(highest_order_diff_west_ == -1,
00173                       __FILE__, __LINE__, __func__);
00174   mtk::Tools::Prevent(highest_order_diff_east_ == -1,
00175                       __FILE__, __LINE__, __func__);
00176   mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00177   mtk::Tools::Prevent(matrix.num_cols() == 0, __FILE__, __LINE__, __func__);
00178   #endif
00179
00182   matrix.SetValue(0, 0, (west_coefficients_[0])(time));
00183
00185   matrix.SetValue(matrix.num_rows() - 1,
00186                   matrix.num_cols() - 1,
00187                   (east_coefficients_[0])(time));
00188
00190   if (highest_order_diff_west_ > 0) {
00191
00193     mtk::Grad1D grad;
00194     if (!grad.ConstructGrad1D(lap.order_accuracy(),
00195                               lap.mimetic_threshold())) {
00196       return false;
00197     }
00198
00200
00204     mtk::DenseMatrix coeffs(grad.mim_bndy());
00205
00206     mtk::Real idx = mtk::kOne/lap.delta();
00207
00209     for (int ii = 0; ii < coeffs.num_cols(); ++ii) {
00211       mtk::Real aux{idx*coeffs.GetValue(0, ii)};
00214       mtk::Real unit_normal{-mtk::kOne};
00215       aux *= unit_normal*(west_coefficients_[1])(time);
00217       matrix.SetValue(0, ii, matrix.GetValue(0, ii) + aux);
00218     }
00219
00221
00226
00227     for (int ii = 0; ii < coeffs.num_cols(); ++ii) {
00229       mtk::Real aux{idx*coeffs.GetValue(0, ii)};
00233       mtk::Real unit_normal{mtk::kOne};
00234       aux *= -unit_normal*(east_coefficients_[1])(time);
00236       matrix.SetValue(matrix.num_rows() - 1,
00237                       matrix.num_rows() - 1 - ii,
00238                       matrix.GetValue(matrix.num_rows() - 1,
00239                                       matrix.num_rows() - 1 -ii) + aux);
00240     }
00241   }
00242
00243   return true;
00244 }
00245
00246 void mtk::RobinBCDescriptor1D::ImposeOnGrid(
00247     UniStgGrid1D &grid,
00248     const mtk::Real &time) const {
00249
00250   #ifdef MTK_PERFORM_PREVENTIONS
00251   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00252   mtk::Tools::Prevent(west_condition_ == nullptr, __FILE__, __LINE__, __func__);
00253   mtk::Tools::Prevent(east_condition_ == nullptr, __FILE__, __LINE__, __func__);
00254   #endif
00255
00256   (grid.discrete_field())[0] = west_condition_(time);
00257   (grid.discrete_field())[grid.num_cells_x() + 1] = east_condition_(time);
00258 }
```

18.117 src/mtk_robin_bc_descriptor_2d.cc File Reference

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

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

Include dependency graph for mtk_robin_bc_descriptor_2d.cc:



18.117.1 Detailed Description

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

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

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

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

Instances of this class receive information about the coefficient functions and each condition for any subset of the boundary (west, east, south and north in 2D). These instances then handle the complexity of placing the coefficients in the differentiation matrices and the conditions in the grids.

See also

http://mathworld.wolfram.com/NormalVector.html

Author

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

Definition in file mtk_robin_bc_descriptor_2d.cc.

18.118 mtk_robin_bc_descriptor_2d.cc

```
00001
00034 /*
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00036 University. All rights reserved.
00037
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00039 are permitted provided that the following conditions are met:
00040
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00042 and a copy of the modified files should be reported once modifications are
00043 completed, unless these modifications are made through the project's GitHub
00044 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00045 should be developed and included in any deliverable.
00046
00047 2. Redistributions of source code must be done through direct
00048 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00051 this list of conditions and the following disclaimer in the documentation and/or
00052 other materials provided with the distribution.
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00075 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00076 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00077 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00078 */
00079
00080 #include "mtk_tools.h"
00081
00082 #include "mtk_robin_bc_descriptor_2d.h"
00083
00084 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D():
00085   highest_order_diff_west_(-1),
00086   highest_order_diff_east_(-1),
00087   highest_order_diff_south_(-1),
00088   highest_order_diff_north_(-1),
00089   west_condition_(),
00090   east_condition_(),
00091   south_condition_(),
00092   north_condition_() {}
00093
00094 mtk::RobinBCDescriptor2D::RobinBCDescriptor2D(
00095     const mtk::RobinBCDescriptor2D &desc):
00096   highest_order_diff_west_(desc.highest_order_diff_west_),
00097   highest_order_diff_east_(desc.highest_order_diff_east_),
00098   highest_order_diff_south_(desc.highest_order_diff_south_),
00099   highest_order_diff_north_(desc.highest_order_diff_north_),
00100   west_condition_(desc.west_condition_),
00101   east_condition_(desc.east_condition_),
00102   south_condition_(desc.south_condition_),
00103   north_condition_(desc.north_condition_) {}
00104
00105 mtk::RobinBCDescriptor2D::~RobinBCDescriptor2D() noexcept {}
00106
00107 int mtk::RobinBCDescriptor2D::highest_order_diff_west()
     const noexcept {
00108
00109   return highest_order_diff_west_;
```

```
00110 }
00111
00112 int mtk::RobinBCDescriptor2D::highest_order_diff_east()
      const noexcept {
00113
00114   return highest_order_diff_east_;
00115 }
00116
00117 int mtk::RobinBCDescriptor2D::highest_order_diff_south()
      const noexcept {
00118
00119   return highest_order_diff_south_;
00120 }
00121
00122 int mtk::RobinBCDescriptor2D::highest_order_diff_north()
      const noexcept {
00123
00124   return highest_order_diff_north_;
00125 }
00126
00127 void mtk::RobinBCDescriptor2D::PushBackWestCoeff(
00128     mtk::CoefficientFunction1D cw) {
00129
00130   #ifdef MTK_PERFORM_PREVENTIONS
00131   mtk::Tools::Prevent(cw == nullptr, __FILE__, __LINE__, __func__);
00132   mtk::Tools::Prevent(highest_order_diff_west_ > 1,
00133                       __FILE__, __LINE__, __func__);
00134   #endif
00135
00136   west_coefficients_.push_back(cw);
00137
00138   highest_order_diff_west_++;
00139 }
00140
00141 void mtk::RobinBCDescriptor2D::PushBackEastCoeff(
00142     mtk::CoefficientFunction1D ce) {
00143
00144   #ifdef MTK_PERFORM_PREVENTIONS
00145   mtk::Tools::Prevent(ce == nullptr, __FILE__, __LINE__, __func__);
00146   mtk::Tools::Prevent(highest_order_diff_east_ > 1,
00147                       __FILE__, __LINE__, __func__);
00148   #endif
00149
00150   east_coefficients_.push_back(ce);
00151
00152   highest_order_diff_east_++;
00153 }
00154
00155 void mtk::RobinBCDescriptor2D::PushBackSouthCoeff(
00156     mtk::CoefficientFunction1D cs) {
00157
00158   #ifdef MTK_PERFORM_PREVENTIONS
00159   mtk::Tools::Prevent(cs == nullptr, __FILE__, __LINE__, __func__);
00160   mtk::Tools::Prevent(highest_order_diff_south_ > 1,
00161                       __FILE__, __LINE__, __func__);
00162   #endif
00163
00164   south_coefficients_.push_back(cs);
00165
00166   highest_order_diff_south_++;
00167 }
00168
00169 void mtk::RobinBCDescriptor2D::PushBackNorthCoeff(
00170     mtk::CoefficientFunction1D cn) {
00171
00172   #ifdef MTK_PERFORM_PREVENTIONS
00173   mtk::Tools::Prevent(cn == nullptr, __FILE__, __LINE__, __func__);
00174   mtk::Tools::Prevent(highest_order_diff_north_ > 1,
00175                       __FILE__, __LINE__, __func__);
00176   #endif
00177
00178   north_coefficients_.push_back(cn);
00179
00180   highest_order_diff_north_++;
00181 }
00182
00183 void mtk::RobinBCDescriptor2D::set_west_condition(
00184     mtk::Real (*west_condition)(const mtk::Real &yy,
00185                                 const mtk::Real &tt)) noexcept {
00186
00187   #ifdef MTK_PERFORM_PREVENTIONS
```

```
00188   mtk::Tools::Prevent(west_condition == nullptr, __FILE__, __LINE__, __func__);
00189   #endif
00190
00191   west_condition_ = west_condition;
00192 }
00193
00194 void mtk::RobinBCDescriptor2D::set_east_condition(
00195     mtk::Real (*east_condition)(const mtk::Real &yy,
00196                                 const mtk::Real &tt)) noexcept {
00197
00198   #ifdef MTK_PERFORM_PREVENTIONS
00199   mtk::Tools::Prevent(east_condition == nullptr, __FILE__, __LINE__, __func__);
00200   #endif
00201
00202   east_condition_ = east_condition;
00203 }
00204
00205 void mtk::RobinBCDescriptor2D::set_south_condition(
00206     mtk::Real (*south_condition)(const mtk::Real &xx,
00207                                  const mtk::Real &tt)) noexcept {
00208
00209   #ifdef MTK_PERFORM_PREVENTIONS
00210   mtk::Tools::Prevent(south_condition == nullptr,
00211                       __FILE__, __LINE__, __func__);
00212   #endif
00213
00214   south_condition_ = south_condition;
00215 }
00216
00217 void mtk::RobinBCDescriptor2D::set_north_condition(
00218     mtk::Real (*north_condition)(const mtk::Real &xx,
00219                                  const mtk::Real &tt)) noexcept {
00220
00221   #ifdef MTK_PERFORM_PREVENTIONS
00222   mtk::Tools::Prevent(north_condition == nullptr,
00223                       __FILE__, __LINE__, __func__);
00224   #endif
00225
00226   north_condition_ = north_condition;
00227 }
00228
00229 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryNoSpace
     (
00230     const mtk::Lap2D &lap,
00231     const mtk::UniStgGrid2D &grid,
00232     mtk::DenseMatrix &matrix,
00233     const mtk::Real &time) const {
00234
00236
00237   // For the south-west corner:
00238   auto cc = (south_coefficients_[0])(grid.west_bndy(), time);
00239
00240   #if MTK_VERBOSE_LEVEL > 2
00241   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00242     matrix.num_cols() << " columns." << std::endl;
00243   std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00244   #endif
00245
00246   matrix.SetValue(0, 0, cc);
00247
00248   // Compute first centers per dimension.
00249   auto first_center_x = grid.west_bndy() + grid.delta_x()/
     mtk::kTwo;
00250
00251   // For each entry on the diagonal (south boundary):
00252   for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00253     // Evaluate next set spatial coordinates to evaluate the coefficient.
00254     mtk::Real xx = first_center_x + ii*grid.delta_x();
00255     // Evaluate and assign the Dirichlet coefficient.
00256     cc = (south_coefficients_[0])(xx, time);
00257
00258     #if MTK_VERBOSE_LEVEL > 2
00259     std::cout << "Setting at " << ii + 1 << ' ' << ii + 1 << std::endl;
00260     #endif
00261
00262     matrix.SetValue(ii + 1, ii + 1, cc);
00263   }
00264
00265   // For the south-east corner:
00266   cc = (south_coefficients_[0])(grid.east_bndy(), time);
00267
```

```
00268   #if MTK_VERBOSE_LEVEL > 2
00269   std::cout << "Setting at " << grid.num_cells_x() + 1 << ' ' <<
00270     grid.num_cells_x() + 1 << std::endl;
00271   #endif
00272
00273   matrix.SetValue(grid.num_cells_x() + 1, grid.num_cells_x() + 1, cc);
00274
00275   if (highest_order_diff_south_ > 0) {
00276
00278   }
00280
00281   return true;
00282 }
00283
00284 bool mtk::RobinBCDescriptor2D::ImposeOnSouthBoundaryWithSpace
      (
00285     const mtk::Lap2D &lap,
00286     const mtk::UniStgGrid2D &grid,
00287     mtk::DenseMatrix &matrix,
00288     const mtk::Real &time) const {
00289
00291
00294
00295   // For each entry on the diagonal:
00296   for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00297     // Evaluate next set spatial coordinates to evaluate the coefficient.
00298     mtk::Real xx{(grid.discrete_domain_x())[ii]};
00299     // Evaluate and assign the Dirichlet coefficient.
00300     mtk::Real cc = (south_coefficients_[0])(xx, time);
00301     matrix.SetValue(ii, ii, cc);
00302   }
00303
00304   if (highest_order_diff_south_ > 0) {
00305
00307   }
00308
00309   return true;
00310 }
00311
00312 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryNoSpace
      (
00313     const mtk::Lap2D &lap,
00314     const mtk::UniStgGrid2D &grid,
00315     mtk::DenseMatrix &matrix,
00316     const mtk::Real &time) const {
00317
00318   int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00319
00321
00322   // For the north-west corner:
00323   mtk::Real cc =
00324     (north_coefficients_[0])(grid.west_bndy(), time);
00325
00326   #if MTK_VERBOSE_LEVEL > 2
00327   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00328     matrix.num_cols() << " columns." << std::endl;
00329   std::cout << "Setting at " << north_offset << ' ' << north_offset <<
00330     std::endl;
00331   #endif
00332
00333   matrix.SetValue(north_offset, north_offset, cc);
00334
00335   // Compute first centers per dimension.
00336   auto first_center_x = grid.west_bndy() + grid.delta_x()/
      mtk::kTwo;
00337
00338   // For each entry on the diagonal (north boundary):
00339   for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00340     // Evaluate next set spatial coordinates to evaluate the coefficient.
00341     mtk::Real xx = first_center_x + ii*grid.delta_x();
00342     // Evaluate and assign the Dirichlet coefficient.
00343     cc = (north_coefficients_[0])(xx, time);
00344
00345     #if MTK_VERBOSE_LEVEL > 2
00346     std::cout << "Setting at " << north_offset + ii + 1 << ' ' <<
00347       north_offset + ii + 1 << std::endl;
00348     #endif
00349
00350     matrix.SetValue(north_offset + ii + 1, north_offset + ii + 1, cc);
00351   }
00352
```

```
00353   // For the north-east corner:
00354   cc = (north_coefficients_[0])(grid.east_bndy(), time);
00355
00356   #if MTK_VERBOSE_LEVEL > 2
00357   std::cout << "Setting at " << north_offset + grid.num_cells_x() + 1 <<
00358     ' ' << north_offset + grid.num_cells_x() + 1 << std::endl;
00359   #endif
00360
00361   matrix.SetValue(north_offset + grid.num_cells_x() + 1,
00362                   north_offset + grid.num_cells_x() + 1, cc);
00363
00364   if (highest_order_diff_north_ > 0) {
00365
00367   }
00368
00369   return true;
00370 }
00371
00372 bool mtk::RobinBCDescriptor2D::ImposeOnNorthBoundaryWithSpace
      (
00373     const mtk::Lap2D &lap,
00374     const mtk::UniStgGrid2D &grid,
00375     mtk::DenseMatrix &matrix,
00376     const mtk::Real &time) const {
00377
00379
00380   int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00381
00383   for (int ii = 0; ii < grid.num_cells_x() + 2; ++ii) {
00385     mtk::Real xx{(grid.discrete_domain_x())[ii]};
00387     mtk::Real cc = (north_coefficients_[0])(xx, time);
00388     matrix.SetValue(north_offset + ii, north_offset + ii, cc);
00389   }
00390
00391   if (highest_order_diff_north_ > 0) {
00392
00394   }
00395
00396   return true;
00397 }
00398
00399 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryNoSpace
      (
00400     const mtk::Lap2D &lap,
00401     const mtk::UniStgGrid2D &grid,
00402     mtk::DenseMatrix &matrix,
00403     const mtk::Real &time) const {
00404
00406
00407   // For the south-west corner:
00408   auto cc = (west_coefficients_[0])(grid.south_bndy(), time);
00409
00410   #if MTK_VERBOSE_LEVEL > 2
00411   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00412     matrix.num_cols() << " columns." << std::endl;
00413   std::cout << "Setting at " << 0 << ' ' << 0 << std::endl;
00414   #endif
00415
00419
00420   mtk::Real harmonic_mean = mtk::kOne/matrix.GetValue(0, 0) +
      mtk::kOne/cc;
00421   harmonic_mean = mtk::kTwo/harmonic_mean;
00422
00423   matrix.SetValue(0, 0, harmonic_mean);
00424
00425   int west_offset{grid.num_cells_x() + 1};
00426
00427   auto first_center_y = grid.south_bndy() + grid.delta_y()/
      mtk::kTwo;
00428
00429   // For each west entry on the diagonal (west boundary):
00430   for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00431     // Evaluate next set spatial coordinates to evaluate the coefficient.
00432     mtk::Real yy = first_center_y + ii*grid.delta_y();
00433     // Evaluate and assign the Dirichlet coefficient.
00434     cc = (west_coefficients_[0])(yy, time);
00435
00436     #if MTK_VERBOSE_LEVEL > 2
00437     std::cout << "Setting at " << west_offset + ii + 1 << ' ' <<
00438       west_offset + ii + 1 << std::endl;
00439     #endif
```

```
00440
00441     matrix.SetValue(west_offset + ii + 1, west_offset + ii + 1, cc);
00442
00443     west_offset += grid.num_cells_x() + 1;
00444   }
00445
00446   // For the north-west corner:
00447   cc = (west_coefficients_[0])(grid.north_bndy(), time);
00448
00449   west_offset += grid.num_cells_x() + 1;
00450   int aux{west_offset};
00451   #if MTK_VERBOSE_LEVEL > 2
00452   std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00453   #endif
00454
00455   harmonic_mean = mtk::kOne/matrix.GetValue(aux, aux) +
      mtk::kOne/cc;
00456   harmonic_mean = mtk::kTwo/harmonic_mean;
00457
00458   matrix.SetValue(aux, aux, harmonic_mean);
00459
00460   if (highest_order_diff_west_ > 0) {
00461
00463   }
00464
00465   return true;
00466 }
00467
00468 bool mtk::RobinBCDescriptor2D::ImposeOnWestBoundaryWithSpace
      (
00469     const mtk::Lap2D &lap,
00470     const mtk::UniStgGrid2D &grid,
00471     mtk::DenseMatrix &matrix,
00472     const mtk::Real &time) const {
00473
00475
00476   int west_offset{grid.num_cells_x() + 1};
00477   // For each west entry on the diagonal:
00478   for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00479     // Evaluate next set spatial coordinates to evaluate the coefficient.
00480     mtk::Real yy{(grid.discrete_domain_y())[ii]};
00481     // Evaluate and assign the Dirichlet coefficient.
00482     mtk::Real cc = (west_coefficients_[0])(yy, time);
00483     matrix.SetValue(west_offset + ii, west_offset + ii, cc);
00484     west_offset += grid.num_cells_x() + 1;
00485   }
00486
00487   if (highest_order_diff_west_ > 0) {
00488
00490   }
00491
00492   return true;
00493 }
00494
00495 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryNoSpace
      (
00496     const mtk::Lap2D &lap,
00497     const mtk::UniStgGrid2D &grid,
00498     mtk::DenseMatrix &matrix,
00499     const mtk::Real &time) const {
00500
00502
00503   // For the south-east corner:
00504   auto cc = (east_coefficients_[0])(grid.south_bndy(), time);
00505
00506   int east_offset{grid.num_cells_x() + 1};
00507   #if MTK_VERBOSE_LEVEL > 2
00508   std::cout << "Matrix has " << matrix.num_rows() << " rows and " <<
00509     matrix.num_cols() << " columns." << std::endl;
00510   std::cout << "Setting at " << east_offset << ' ' << east_offset <<
00511     std::endl;
00512   #endif
00513
00514   mtk::Real harmonic_mean =
00515     mtk::kOne/matrix.GetValue(east_offset,east_offset) +
      mtk::kOne/cc;
00516   harmonic_mean = mtk::kTwo/harmonic_mean;
00517
00518   matrix.SetValue(east_offset, east_offset, harmonic_mean);
00519
00520   auto first_center_y = grid.south_bndy() + grid.delta_y()/
```

```
      mtk::kTwo;
00521
00522   // For each east entry on the diagonal (east boundary):
00523   for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00524
00525     east_offset += grid.num_cells_x() + 1;
00526
00527     // Evaluate next set spatial coordinates to evaluate the coefficient.
00528     mtk::Real yy = first_center_y + ii*grid.delta_y();
00529     // Evaluate and assign the Dirichlet coefficient.
00530     cc = (east_coefficients_[0])(yy, time);
00531
00532     #if MTK_VERBOSE_LEVEL > 2
00533     std::cout << "Setting at " << east_offset + ii + 1 << ' ' <<
00534       east_offset + ii + 1 << std::endl;
00535     #endif
00536
00537     matrix.SetValue(east_offset + ii + 1, east_offset + ii + 1, cc);
00538   }
00539
00540   // For the north-east corner:
00541   cc = (east_coefficients_[0])(grid.north_bndy(), time);
00542
00543   east_offset += grid.num_cells_x() + 1;
00544   east_offset += grid.num_cells_x() + 1;
00545   int aux{east_offset};
00546   #if MTK_VERBOSE_LEVEL > 2
00547   std::cout << "Setting at " << aux << ' ' << aux << std::endl;
00548   #endif
00549
00550   harmonic_mean =
00551     mtk::kOne/matrix.GetValue(aux, aux) + mtk::kOne/cc;
00552   harmonic_mean = mtk::kTwo/harmonic_mean;
00553
00554   matrix.SetValue(aux, aux, harmonic_mean);
00555
00556   if (highest_order_diff_east_ > 0) {
00557
00559   }
00560
00561   return true;
00562 }
00563
00564 bool mtk::RobinBCDescriptor2D::ImposeOnEastBoundaryWithSpace
      (
00565     const mtk::Lap2D &lap,
00566     const mtk::UniStgGrid2D &grid,
00567     mtk::DenseMatrix &matrix,
00568     const mtk::Real &time) const {
00569
00571
00572   int east_offset{grid.num_cells_x() + 1};
00573   // For each west entry on the diagonal:
00574   for (int ii = 0; ii < grid.num_cells_y() + 2; ++ii) {
00575     east_offset += grid.num_cells_x() + 1;
00576     // Evaluate next set spatial coordinates to evaluate the coefficient.
00577     mtk::Real yy{(grid.discrete_domain_y())[ii]};
00578     // Evaluate and assign the arithmetic mean of Dirichlet coefficients.
00579     mtk::Real cc = (east_coefficients_[0])(yy, time);
00580     matrix.SetValue(east_offset + ii, east_offset + ii, cc);
00581   }
00582
00583   if (highest_order_diff_east_ > 0) {
00584
00586   }
00587
00588   return true;
00589 }
00590
00591 bool mtk::RobinBCDescriptor2D::ImposeOnLaplacianMatrix(
00592     const mtk::Lap2D &lap,
00593     const mtk::UniStgGrid2D &grid,
00594     mtk::DenseMatrix &matrix,
00595     const mtk::Real &time) const {
00596
00597   #ifdef MTK_PERFORM_PREVENTIONS
00598   mtk::Tools::Prevent(highest_order_diff_south_ == -1,
00599                       __FILE__, __LINE__, __func__);
00600   mtk::Tools::Prevent(highest_order_diff_north_ == -1,
00601                       __FILE__, __LINE__, __func__);
00602   mtk::Tools::Prevent(highest_order_diff_west_ == -1,
```

```
00603                       __FILE__, __LINE__, __func__);
00604   mtk::Tools::Prevent(highest_order_diff_east_ == -1,
00605                       __FILE__, __LINE__, __func__);
00606   mtk::Tools::Prevent(grid.nature() !=
      mtk::FieldNature::SCALAR,
00607                       __FILE__, __LINE__, __func__);
00608   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00609   mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00610   mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00611   mtk::Tools::Prevent(matrix.num_cols() == 0, __FILE__, __LINE__, __func__);
00612   #endif
00613
00616
00617   bool success{true};
00618
00619   if (!grid.Bound()) {
00620     success = ImposeOnSouthBoundaryNoSpace(lap, grid, matrix, time);
00621     #ifdef MTK_PERFORM_PREVENTIONS
00622     if (!success) {
00623       return false;
00624     }
00625     #endif
00626     success = ImposeOnNorthBoundaryNoSpace(lap, grid, matrix, time);
00627     #ifdef MTK_PERFORM_PREVENTIONS
00628     if (!success) {
00629       return false;
00630     }
00631     #endif
00632     success = ImposeOnWestBoundaryNoSpace(lap, grid, matrix, time);
00633     #ifdef MTK_PERFORM_PREVENTIONS
00634     if (!success) {
00635       return false;
00636     }
00637     #endif
00638     success = ImposeOnEastBoundaryNoSpace(lap, grid, matrix, time);
00639     #ifdef MTK_PERFORM_PREVENTIONS
00640     if (!success) {
00641       return false;
00642     }
00643     #endif
00644   } else {
00645     success = ImposeOnSouthBoundaryWithSpace(lap, grid, matrix, time);
00646     #ifdef MTK_PERFORM_PREVENTIONS
00647     if (!success) {
00648       return false;
00649     }
00650     #endif
00651     success = ImposeOnNorthBoundaryWithSpace(lap, grid, matrix, time);
00652     #ifdef MTK_PERFORM_PREVENTIONS
00653     if (!success) {
00654       return false;
00655     }
00656     #endif
00657     success = ImposeOnWestBoundaryWithSpace(lap, grid, matrix, time);
00658     #ifdef MTK_PERFORM_PREVENTIONS
00659     if (!success) {
00660       return false;
00661     }
00662     #endif
00663     success = ImposeOnEastBoundaryWithSpace(lap, grid, matrix, time);
00664     #ifdef MTK_PERFORM_PREVENTIONS
00665     if (!success) {
00666       return false;
00667     }
00668     #endif
00669   }
00670
00671   return success;
00672 }
00673
00674 void mtk::RobinBCDescriptor2D::ImposeOnGrid(
00675     mtk::UniStgGrid2D &grid,
00676     const mtk::Real &time) const {
00677
00678   #ifdef MTK_PERFORM_PREVENTIONS
00679   mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00680   mtk::Tools::Prevent(grid.num_cells_y() == 0, __FILE__, __LINE__, __func__);
00681   mtk::Tools::Prevent(west_condition_ == nullptr, __FILE__, __LINE__, __func__);
00682   mtk::Tools::Prevent(east_condition_ == nullptr, __FILE__, __LINE__, __func__);
00683   mtk::Tools::Prevent(south_condition_ == nullptr,
00684                       __FILE__, __LINE__, __func__);
```

```
00685   mtk::Tools::Prevent(north_condition_ == nullptr,
00686                       __FILE__, __LINE__, __func__);
00687   #endif
00688
00690   if (grid.nature() == mtk::FieldNature::SCALAR) {
00691
00693
00695     mtk::Real xx = grid.west_bndy();
00696     (grid.discrete_field())[0] = south_condition_(xx, time);
00697
00699     xx = xx + grid.delta_x()/mtk::kTwo;
00700     // For every point on the south boundary:
00701     for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00702       (grid.discrete_field())[ii + 1] =
00703         south_condition_(xx + ii*grid.delta_x(), time);
00704     }
00705
00707     xx = grid.east_bndy();
00708     (grid.discrete_field())[grid.num_cells_x() + 1] =
00709       south_condition_(xx, time);
00710
00712
00714     xx = grid.west_bndy();
00715     int north_offset{(grid.num_cells_y() + 1)*(grid.num_cells_x() + 2)};
00716     (grid.discrete_field())[north_offset] = north_condition_(xx, time);
00717
00719     xx = xx + grid.delta_x()/mtk::kTwo;
00720     for (int ii = 0; ii < grid.num_cells_x(); ++ii) {
00721       (grid.discrete_field())[north_offset + ii + 1] =
00722         north_condition_(xx + ii*grid.delta_x(), time);
00723     }
00724
00726     xx = grid.east_bndy();
00727     (grid.discrete_field())[north_offset + grid.num_cells_x() + 1] =
00728         north_condition_(xx, time);
00729
00731
00735     mtk::Real yy = grid.south_bndy();
00736     (grid.discrete_field())[0] =
00737       ((grid.discrete_field())[0] + west_condition_(yy, time))/
      mtk::kTwo;
00738
00740     int west_offset{grid.num_cells_x() + 1 + 1};
00741     yy = yy + grid.delta_y()/mtk::kTwo;
00742     for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00743       #if MTK_VERBOSE_LEVEL > 2
00744       std::cout << "Adding on " << west_offset << "-th position." << std::endl;
00745       #endif
00746       (grid.discrete_field())[west_offset] =
00747         west_condition_(yy + ii*grid.delta_y(), time);
00748       west_offset += grid.num_cells_x() + 1 + 1;
00749     }
00750
00752     yy = grid.north_bndy();
00753     north_offset = (grid.num_cells_y() + 1)*(grid.num_cells_x() + 2);
00754     (grid.discrete_field())[north_offset] =
00755       ((grid.discrete_field())[north_offset] + west_condition_(yy, time))/
00756         mtk::kTwo;
00757
00759
00761     yy = grid.south_bndy();
00762     int east_offset{grid.num_cells_x() + 1};
00763     (grid.discrete_field())[east_offset] =
00764       ((grid.discrete_field())[east_offset] + east_condition_(yy, time))/
00765         mtk::kTwo;
00766
00768     yy = yy + grid.delta_y()/mtk::kTwo;
00769     for (int ii = 0; ii < grid.num_cells_y(); ++ii) {
00770       east_offset += grid.num_cells_x() + 1 + 1;
00771       #if MTK_VERBOSE_LEVEL > 2
00772       std::cout << "Adding on " << east_offset << "-th position." << std::endl;
00773       #endif
00774       (grid.discrete_field())[east_offset] =
00775         east_condition_(yy + ii*grid.delta_y(), time);
00776     }
00777
00779     yy = grid.north_bndy();
00780     (grid.discrete_field())[north_offset + grid.num_cells_x() + 1] =
00781       ((grid.discrete_field())[north_offset + grid.num_cells_x() + 1] +
00782       east_condition_(yy, time))/mtk::kTwo;
00783
```

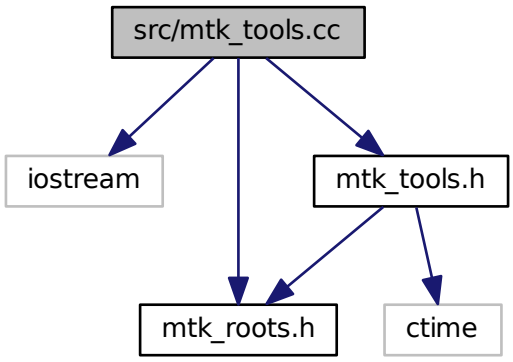
```
00784   } else {
00785
00787
00789   }
00790 }
```

18.119 src/mtk_tools.cc File Reference

Tool manager class.

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

Include dependency graph for mtk_tools.cc:



18.119.1 Detailed Description

Implementation of a class providing basic tools to ensure execution correctness, and to assists with unitary testing.

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Definition in file mtk_tools.cc.

18.120 mtk_tools.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
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <iostream>
00058
00059 #include "mtk_roots.h"
00060 #include "mtk_tools.h"
00061
00062 void mtk::Tools::Prevent(const bool condition,
00063                          const char *const fname,
00064                          int lineno,
00065                          const char *const fxname) noexcept {
00066
00068   if (lineno < 1) {
00069     std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00070     __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00071     exit(EXIT_FAILURE);
00072   }
00073
00074   if (condition) {
00075     std::cerr << fname << ": " << "Incorrect parameter at line " <<
00076     lineno << " (" << fxname << ")" << std::endl;
00077     exit(EXIT_FAILURE);
00078   }
00079 }
00080
00081 int mtk::Tools::test_number_{};   // Current test being executed.
00082
00083 mtk::Real mtk::Tools::duration_{};    // Duration of the current test.
00084
00085 clock_t mtk::Tools::begin_time_{};  // Elapsed time on current test.
00086
00087 void mtk::Tools::BeginUnitTestNo(const int &nn) noexcept {
00088
00089   #if MTK_PERFORM_PREVENTIONS
00090   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00091   #endif
00092
00093   test_number_ = nn;
00094
00095   std::cout << "Beginning test " << nn << "." << std::endl;
00096   begin_time_ = clock();
00097 }
00098
00099 void mtk::Tools::EndUnitTestNo(const int &nn) noexcept {
```

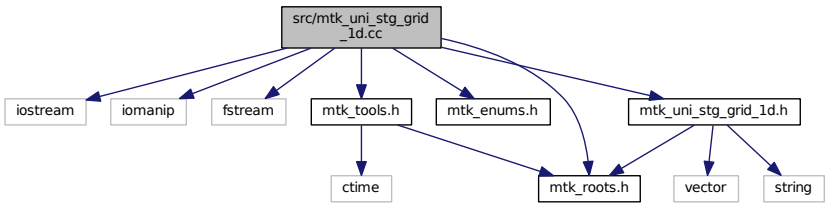
```
00100
00101   #if MTK_PERFORM_PREVENTIONS
00102   mtk::Tools::Prevent(test_number_ != nn, __FILE__, __LINE__, __func__);
00103   #endif
00104
00105   duration_ = mtk::Real(clock() - begin_time_)/CLOCKS_PER_SEC;
00106 }
00107
00108 void mtk::Tools::Assert(const bool &condition) noexcept {
00109
00110   if (condition) {
00111     std::cout << "Test " << test_number_ << ": PASSED in " << duration_ <<
00112       " s." << std::endl;
00113   } else {
00114     std::cout << "Test " << test_number_ << ": FAILED in " << duration_ <<
00115       " s." << std::endl;
00116   }
00117 }
```

18.121 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)

18.121.1 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.

18.122 mtk_uni_stg_grid_1d.cc

```
00001
00010 /*
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00013
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_enums.h"
00062 #include "mtk_tools.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00068 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid1D &in) {
00069
00070   stream << '[' << in.west_bndy_x_ << ':' << in.num_cells_x_ << ':' <<
00071   in.east_bndy_x_ << "] = " << std::endl << std::endl;
00072
00074
00075   stream << "x:";
00076   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00077     stream << std::setw(10) << in.discrete_domain_x_[ii];
```

```
00078   }
00079   stream << std::endl;
00080
00082
00083   if (in.nature_ == mtk::FieldNature::SCALAR) {
00084     stream << "u:";
00085   }
00086   else {
00087     stream << "v:";
00088   }
00089   for (unsigned int ii = 0; ii < in.discrete_field_.size(); ++ii) {
00090     stream << std::setw(10) << in.discrete_field_[ii];
00091   }
00092
00093   stream << std::endl;
00094
00095   return stream;
00096 }
00097 }
00098
00099 mtk::UniStgGrid1D::UniStgGrid1D():
00100     nature_(),
00101     discrete_domain_x_(),
00102     discrete_field_(),
00103     west_bndy_x_(),
00104     east_bndy_x_(),
00105     num_cells_x_(),
00106     delta_x_() {}
00107
00108 mtk::UniStgGrid1D::UniStgGrid1D(const
      UniStgGrid1D &grid):
00109     nature_(grid.nature_),
00110     west_bndy_x_(grid.west_bndy_x_),
00111     east_bndy_x_(grid.east_bndy_x_),
00112     num_cells_x_(grid.num_cells_x_),
00113     delta_x_(grid.delta_x_) {
00114
00115     std::copy(grid.discrete_domain_x_.begin(),
00116               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00117               discrete_domain_x_.begin());
00118
00119     std::copy(grid.discrete_field_.begin(),
00120               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00121               discrete_field_.begin());
00122 }
00123
00124 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00125                                 const Real &east_bndy_x,
00126                                 const int &num_cells_x,
00127                                 const mtk::FieldNature &nature) {
00128
00129   #ifdef MTK_PERFORM_PREVENTIONS
00130   mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00131   mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00132   mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00133   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00134   #endif
00135
00136   nature_ = nature;
00137   west_bndy_x_ = west_bndy_x;
00138   east_bndy_x_ = east_bndy_x;
00139   num_cells_x_ = num_cells_x;
00140
00141   delta_x_ = (east_bndy_x - west_bndy_x)/((mtk::Real) num_cells_x);
00142 }
00143
00144 mtk::UniStgGrid1D::~UniStgGrid1D() {}
00145
00146 mtk::Real mtk::UniStgGrid1D::west_bndy_x() const {
00147
00148   return west_bndy_x_;
00149 }
00150
00151 mtk::Real mtk::UniStgGrid1D::east_bndy_x() const {
00152
00153   return east_bndy_x_;
00154 }
00155
00156 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00157
```

```
00158   return delta_x_;
00159 }
00160
00161 const mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() const
    {
00162
00163   return discrete_domain_x_.data();
00164 }
00165
00166 mtk::Real *mtk::UniStgGrid1D::discrete_field() {
00167
00168   return discrete_field_.data();
00169 }
00170
00171 int mtk::UniStgGrid1D::num_cells_x() const {
00172
00173   return num_cells_x_;
00174 }
00175
00176 void mtk::UniStgGrid1D::GenerateDiscreteDomainX() {
00177
00178   #ifdef MTK_PERFORM_PREVENTIONS
00179   mtk::Tools::Prevent(discrete_domain_x_.size() != 0,
00180                       __FILE__, __LINE__, __func__);
00181   #endif
00182
00183   if (nature_ == mtk::FieldNature::SCALAR) {
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
00199   } else {
00200
00201     discrete_domain_x_.reserve(num_cells_x_ + 1);
00202
00203     discrete_domain_x_.push_back(west_bndy_x_);
00204     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00205       discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00206     }
00207     discrete_domain_x_.push_back(east_bndy_x_);
00208   }
00209 }
00210
00211 void mtk::UniStgGrid1D::BindScalarField(
00212     mtk::Real (*ScalarField)(const mtk::Real &xx)) {
00213
00214   #ifdef MTK_PERFORM_PREVENTIONS
00215   mtk::Tools::Prevent(nature_ == mtk::FieldNature::VECTOR,
00216                       __FILE__, __LINE__, __func__);
00217   #endif
00218
00220
00221   discrete_domain_x_.reserve(num_cells_x_ + 2);
00222
00223   discrete_domain_x_.push_back(west_bndy_x_);
00224   #ifdef MTK_PRECISION_DOUBLE
00225   auto first_center = west_bndy_x_ + delta_x_/2.0;
00226   #else
00227   auto first_center = west_bndy_x_ + delta_x_/2.0f;
00228   #endif
00229   discrete_domain_x_.push_back(first_center);
00230   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00231     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00232   }
00233   discrete_domain_x_.push_back(east_bndy_x_);
00234
00236
00237   discrete_field_.reserve(num_cells_x_ + 2);
00238
00239   discrete_field_.push_back(ScalarField(west_bndy_x_));
```

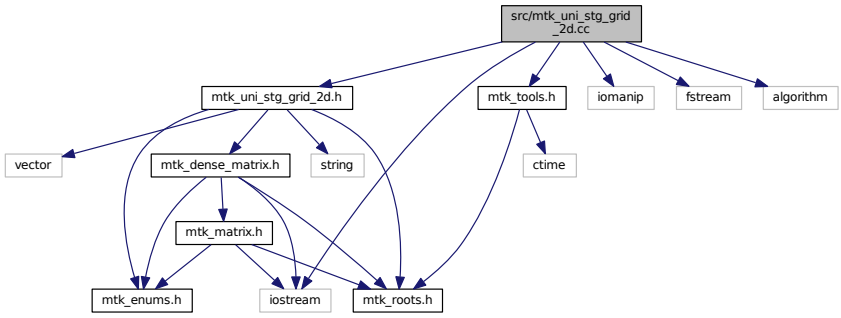
```
00240
00241   discrete_field_.push_back(ScalarField(first_center));
00242   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00243     discrete_field_.push_back(ScalarField(first_center + ii*delta_x_));
00244   }
00245   discrete_field_.push_back(ScalarField(east_bndy_x_));
00246 }
00247
00248 void mtk::UniStgGrid1D::BindVectorField(
00249     mtk::Real (*VectorField)(mtk::Real xx)) {
00250
00251   #ifdef MTK_PERFORM_PREVENTIONS
00252   mtk::Tools::Prevent(nature_ == mtk::FieldNature::SCALAR,
00253                       __FILE__, __LINE__, __func__);
00254   #endif
00255
00257
00258   discrete_domain_x_.reserve(num_cells_x_ + 1);
00259
00260   discrete_domain_x_.push_back(west_bndy_x_);
00261   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00262     discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00263   }
00264   discrete_domain_x_.push_back(east_bndy_x_);
00265
00267
00268   discrete_field_.reserve(num_cells_x_ + 1);
00269
00270   discrete_field_.push_back(VectorField(west_bndy_x_));
00271   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00272     discrete_field_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00273   }
00274   discrete_field_.push_back(VectorField(east_bndy_x_));
00275 }
00276
00277 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00278                                     std::string space_name,
00279                                     std::string field_name) const {
00280
00281   std::ofstream output_dat_file;  // Output file.
00282
00283   output_dat_file.open(filename);
00284
00285   if (!output_dat_file.is_open()) {
00286     return false;
00287   }
00288
00289   output_dat_file << "# " << space_name <<  ' ' << field_name << std::endl;
00290   for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00291     output_dat_file << discrete_domain_x_[ii] << ' ' << discrete_field_[ii] <<
00292       std::endl;
00293   }
00294
00295   output_dat_file.close();
00296
00297   return true;
00298 }
```

18.123 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)

18.123.1 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.

18.124 mtk_uni_stg_grid_2d.cc

```
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00010 /*
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00012 University. All rights reserved.
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00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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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::FieldNature::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_ +
00097 jj];
00098         }
00099         stream << std::endl;
00100       }
00101     }
00102   } else {
00103
00104     int mm{in.num_cells_x_};
00105     int nn{in.num_cells_y_};
00106     int p_offset{nn*(mm + 1) - 1};
00107
00108     stream << "p(x,y):" << std::endl;
```

```
00109     for (int ii = 0; ii < nn; ++ii) {
00110       for (int jj = 0; jj < mm + 1; ++jj) {
00111         stream << std::setw(10) << in.discrete_field_[ii*(mm + 1) + jj];
00112       }
00113       stream << std::endl;
00114     }
00115     stream << std::endl;
00116 
00117     stream << "q(x,y):" << std::endl;
00118     for (int ii = 0; ii < nn + 1; ++ii) {
00119       for (int jj = 0; jj < mm; ++jj) {
00120         stream << std::setw(10) <<
00121           in.discrete_field_[p_offset + ii*mm + jj];
00122       }
00123       stream << std::endl;
00124     }
00125     stream << std::endl;
00126   }
00127 
00128   return stream;
00129 }
00130 }
00131 
00132 mtk::UniStgGrid2D::UniStgGrid2D():
00133     discrete_domain_x_(),
00134     discrete_domain_y_(),
00135     discrete_field_(),
00136     nature_(),
00137     west_bndy_(),
00138     east_bndy_(),
00139     num_cells_x_(),
00140     delta_x_(),
00141     south_bndy_(),
00142     north_bndy_(),
00143     num_cells_y_(),
00144     delta_y_() {}
00145 
00146 mtk::UniStgGrid2D::UniStgGrid2D(const
      UniStgGrid2D &grid):
00147     nature_(grid.nature_),
00148     west_bndy_(grid.west_bndy_),
00149     east_bndy_(grid.east_bndy_),
00150     num_cells_x_(grid.num_cells_x_),
00151     delta_x_(grid.delta_x_),
00152     south_bndy_(grid.south_bndy_),
00153     north_bndy_(grid.north_bndy_),
00154     num_cells_y_(grid.num_cells_y_),
00155     delta_y_(grid.delta_y_) {
00156 
00157     std::copy(grid.discrete_domain_x_.begin(),
00158               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00159               discrete_domain_x_.begin());
00160 
00161     std::copy(grid.discrete_domain_y_.begin(),
00162               grid.discrete_domain_y_.begin() + grid.
      discrete_domain_y_.size(),
00163               discrete_domain_y_.begin());
00164 
00165     std::copy(grid.discrete_field_.begin(),
00166               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00167               discrete_field_.begin());
00168 }
00169 
00170 mtk::UniStgGrid2D::UniStgGrid2D(const Real &west_bndy,
00171                                 const Real &east_bndy,
00172                                 const int &num_cells_x,
00173                                 const Real &south_bndy,
00174                                 const Real &north_bndy,
00175                                 const int &num_cells_y,
00176                                 const mtk::FieldNature &nature) {
00177 
00178   #ifdef MTK_PERFORM_PREVENTIONS
00179   mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00180   mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00182   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00183   mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00184   mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00185   mtk::Tools::Prevent(north_bndy <= south_bndy,
00186                       __FILE__, __LINE__, __func__);
```

```
00187   mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00188   #endif
00189
00190   nature_ = nature;
00191
00192   west_bndy_ = west_bndy;
00193   east_bndy_ = east_bndy;
00194   num_cells_x_ = num_cells_x;
00195
00196   south_bndy_ = south_bndy;
00197   north_bndy_ = north_bndy;
00198   num_cells_y_ = num_cells_y;
00199
00200   delta_x_ = (east_bndy_ - west_bndy_)/((mtk::Real) num_cells_x);
00201   delta_y_ = (north_bndy_ - south_bndy_)/((mtk::Real) num_cells_y);
00202 }
00203
00204 mtk::UniStgGrid2D::~UniStgGrid2D() {}
00205
00206 mtk::FieldNature mtk::UniStgGrid2D::nature() const {
00207
00208   return nature_;
00209 }
00210
00211 mtk::Real mtk::UniStgGrid2D::west_bndy() const {
00212
00213   return west_bndy_;
00214 }
00215
00216 mtk::Real mtk::UniStgGrid2D::east_bndy() const {
00217
00218   return east_bndy_;
00219 }
00220
00221 int mtk::UniStgGrid2D::num_cells_x() const {
00222
00223   return num_cells_x_;
00224 }
00225
00226 mtk::Real mtk::UniStgGrid2D::delta_x() const {
00227
00228   return delta_x_;
00229 }
00230
00231 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_x() const
      {
00232
00233   return discrete_domain_x_.data();
00234 }
00235
00236 mtk::Real mtk::UniStgGrid2D::south_bndy() const {
00237
00238   return south_bndy_;
00239 }
00240
00241 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00242
00243   return north_bndy_;
00244 }
00245
00246 int mtk::UniStgGrid2D::num_cells_y() const {
00247
00248   return num_cells_y_;
00249 }
00250
00251 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00252
00253   return delta_y_;
00254 }
00255
00256 bool mtk::UniStgGrid2D::Bound() const {
00257
00258   return discrete_field_.size() != 0;
00259 }
00260
00261 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_y() const
      {
00262
00263   return discrete_domain_y_.data();
00264 }
00265
```

```
00266 mtk::Real* mtk::UniStgGrid2D::discrete_field() {
00267
00268   return discrete_field_.data();
00269 }
00270
00271 int mtk::UniStgGrid2D::Size() const {
00272
00273   return discrete_field_.size();
00274 }
00275
00276 void mtk::UniStgGrid2D::BindScalarField(
00277     Real (*ScalarField)(const Real &xx, const Real &yy)) {
00278
00279   #ifdef MTK_PERFORM_PREVENTIONS
00280   mtk::Tools::Prevent(nature_ != mtk::FieldNature::SCALAR,
      __FILE__, __LINE__,
00281 __func__);
00282   #endif
00283
00285
00286   discrete_domain_x_.reserve(num_cells_x_ + 2);
00287
00288   discrete_domain_x_.push_back(west_bndy_);
00289   #ifdef MTK_PRECISION_DOUBLE
00290   auto first_center = west_bndy_ + delta_x_/2.0;
00291   #else
00292   auto first_center = west_bndy_ + delta_x_/2.0f;
00293   #endif
00294   discrete_domain_x_.push_back(first_center);
00295   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00296     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00297   }
00298   discrete_domain_x_.push_back(east_bndy_);
00299
00301
00302   discrete_domain_y_.reserve(num_cells_y_ + 2);
00303
00304   discrete_domain_y_.push_back(south_bndy_);
00305   #ifdef MTK_PRECISION_DOUBLE
00306   first_center = south_bndy_ + delta_x_/2.0;
00307   #else
00308   first_center = south_bndy_ + delta_x_/2.0f;
00309   #endif
00310   discrete_domain_y_.push_back(first_center);
00311   for (auto ii = 1; ii < num_cells_y_; ++ii) {
00312     discrete_domain_y_.push_back(first_center + ii*delta_y_);
00313   }
00314   discrete_domain_y_.push_back(north_bndy_);
00315
00317
00318   discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));
00319
00320   for (int ii = 0; ii < num_cells_y_ + 2; ++ii) {
00321     for (int jj = 0; jj < num_cells_x_ + 2; ++jj) {
00322       #if MTK_VERBOSE_LEVEL > 6
00323       std::cout << "Pushing value for x = " << discrete_domain_x_[jj] <<
00324         " y = " << discrete_domain_y_[ii] << std::endl;
00325       #endif
00326       discrete_field_.push_back(ScalarField(discrete_domain_x_[jj],
00327                                             discrete_domain_y_[ii]));
00328     }
00329   }
00330 }
00331
00332 void mtk::UniStgGrid2D::BindVectorFieldPComponent(
00333   mtk::Real (*VectorField)(const mtk::Real &xx, const
      mtk::Real &yy)) {
00334
00335   int mm{num_cells_x_};
00336   int nn{num_cells_y_};
00337
00338   int total{nn*(mm + 1) + mm*(nn + 1)};
00339
00340   #ifdef MTK_PRECISION_DOUBLE
00341   double half_delta_x{delta_x_/2.0};
00342   double half_delta_y{delta_y_/2.0};
00343   #else
00344   float half_delta_x{delta_x_/2.0f};
00345   float half_delta_y{delta_y_/2.0f};
00346   #endif
00347
```

```
00349
00350   // We need every data point of the discrete domain; i.e. we need all the
00351   // nodes and all the centers. There are mm centers for the x direction, and
00352   // nn centers for the y direction. Since there is one node per center, that
00353   // amounts to 2*mm. If we finally consider the final boundary node, it
00354   // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00355   // y direction, this amounts to 2*nn + 1.
00356
00357   discrete_domain_x_.reserve(2*mm + 1);
00358
00359   discrete_domain_x_.push_back(west_bndy_);
00360   for (int ii = 1; ii < (2*mm + 1); ++ii) {
00361     discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00362   }
00363
00365
00366   discrete_domain_y_.reserve(2*nn + 1);
00367
00368   discrete_domain_y_.push_back(south_bndy_);
00369   for (int ii = 1; ii < (2*nn + 1); ++ii) {
00370     discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00371   }
00372
00374
00375   discrete_field_.reserve(total);
00376
00377   // For each y-center.
00378   for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00379
00380     // Bind all of the x-nodes for this y-center.
00381     for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00382       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00383                                             discrete_domain_y_[ii]));
00384
00385       #if MTK_VERBOSE_LEVEL > 6
00386       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00387         discrete_domain_y_[ii] << " = " <<
00388         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00389       #endif
00390     }
00391   }
00392   #if MTK_VERBOSE_LEVEL > 6
00393   std::cout << std::endl;
00394   #endif
00395 }
00396
00397 void mtk::UniStgGrid2D::BindVectorFieldQComponent(
00398   mtk::Real (*VectorField)(const mtk::Real &xx, const
      mtk::Real &yy)) {
00399
00400   int mm{num_cells_x_};
00401   int nn{num_cells_y_};
00402
00404
00405   // For each y-node.
00406   for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00407
00408     // Bind all of the x-center for this y-node.
00409     for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00410       discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00411                                             discrete_domain_y_[ii]));
00412
00413       #if MTK_VERBOSE_LEVEL > 6
00414       std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00415         discrete_domain_y_[ii] << " = " <<
00416         VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00417       #endif
00418     }
00419   }
00420   #if MTK_VERBOSE_LEVEL > 6
00421   std::cout << std::endl;
00422   #endif
00423 }
00424
00425 void mtk::UniStgGrid2D::BindVectorField(
00426   Real (*VectorFieldPComponent)(const Real &xx, const Real &yy),
00427   Real (*VectorFieldQComponent)(const Real &xx, const Real &yy)) {
00428
00429   #ifdef MTK_PERFORM_PREVENTIONS
00430   mtk::Tools::Prevent(nature_ != mtk::FieldNature::VECTOR,
      __FILE__, __LINE__,
```

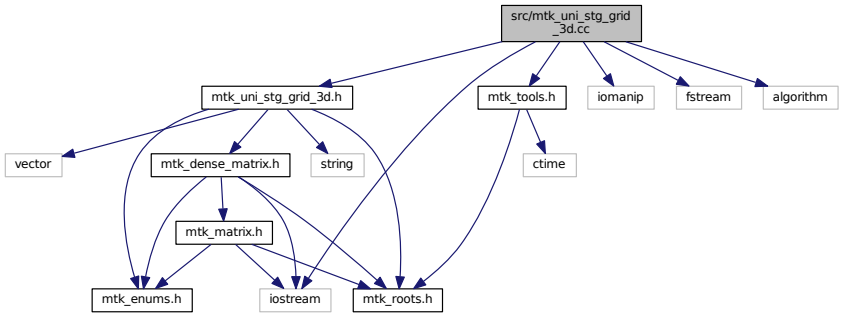
```
00431 __func__);
00432   #endif
00433
00434   BindVectorFieldPComponent(VectorFieldPComponent);
00435   BindVectorFieldQComponent(VectorFieldQComponent);
00436 }
00437
00438 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00439                                     std::string space_name_x,
00440                                     std::string space_name_y,
00441                                     std::string field_name) const {
00442
00443   std::ofstream output_dat_file;  // Output file.
00444
00445   output_dat_file.open(filename);
00446
00447   if (!output_dat_file.is_open()) {
00448     return false;
00449   }
00450
00451   if (nature_ == mtk::FieldNature::SCALAR) {
00452     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00453       field_name << std::endl;
00454
00455     int idx{};
00456     for (unsigned int ii = 0; ii < discrete_domain_y_.size(); ++ii) {
00457       for (unsigned int jj = 0; jj < discrete_domain_x_.size(); ++jj) {
00458         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00459                            discrete_domain_y_[ii] << ' ' <<
00460                            discrete_field_[idx] <<
00461                           std::endl;
00462         idx++;
00463       }
00464       output_dat_file << std::endl;
00465     }
00466   } else {
00467     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00468       field_name << std::endl;
00469
00470     output_dat_file << "# Horizontal component:" << std::endl;
00471
00472     int mm{num_cells_x_};
00473     int nn{num_cells_y_};
00474
00476
00477     // For each y-center.
00478     int idx{};
00479     for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00480       // Bind all of the x-nodes for this y-center.
00481       for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00482
00483         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00484           discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<
00485           mtk::kZero << std::endl;
00486
00487         ++idx;
00488       }
00489     }
00490
00492     int p_offset{nn*(mm + 1) - 1};
00493     idx = 0;
00494     output_dat_file << "# Vertical component:" << std::endl;
00495     // For each y-node.
00496     for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00497       // Bind all of the x-center for this y-node.
00498       for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00499
00500         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00501           discrete_domain_y_[ii] << ' ' << mtk::kZero << ' ' <<
00502           discrete_field_[p_offset + idx] << std::endl;
00503
00504         ++idx;
00505       }
00506     }
00507   }
00508
00509   output_dat_file.close();
00510
00511   return true;
00512 }
```

18.125 src/mtk_uni_stg_grid_3d.cc File Reference

Implementation of a 3D uniform staggered grid.

```
#include <iostream>
#include <iomanip>
#include <fstream>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_3d.h"
```

Include dependency graph for mtk_uni_stg_grid_3d.cc:



Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Functions

- std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid3D &in)

18.125.1 Detailed Description

Implementation of a 3D uniform staggered grid.

Author

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

Definition in file mtk_uni_stg_grid_3d.cc.

18.126 mtk_uni_stg_grid_3d.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
```

```
00013
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00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include <algorithm>
00061
00062 #include "mtk_tools.h"
00063 #include "mtk_uni_stg_grid_3d.h"
00064
00065 namespace mtk {
00066
00067 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid3D &in) {
00068
00069   stream << '[' << in.west_bndy_ << ':' << in.num_cells_x_ << ':' <<
00070   in.east_bndy_ << "] x ";
00071
00072   stream << '[' << in.south_bndy_ << ':' << in.num_cells_y_ << ':' <<
00073   in.north_bndy_ << "] x ";
00074
00075   stream << '[' << in.bottom_bndy_ << ':' << in.num_cells_z_ << ':' <<
00076   in.top_bndy_ << "] = " << std::endl << std::endl;
00077
00079
00080   stream << "x:";
00081   for (auto const &cc: in.discrete_domain_x_) {
00082     stream << std::setw(10) << cc;
00083   }
00084   stream << std::endl;
00085
00086   stream << "y:";
00087   for (auto const &cc: in.discrete_domain_y_) {
00088     stream << std::setw(10) << cc;
00089   }
00090   stream << std::endl;
00091
00092   stream << "z:";
00093   for (auto const &cc: in.discrete_domain_z_) {
00094     stream << std::setw(10) << cc;
```

```
00095   }
00096   stream << std::endl;
00097
00099
00100   if (in.nature_ == mtk::FieldNature::SCALAR) {
00101     stream << "u(x,y,z):" << std::endl;
00102     if (in.discrete_field_.size() > 0) {
00103
00104     }
00105   } else {
00106     stream << "p(x,y,z):" << std::endl;
00107     stream << "q(x,y.z):" << std::endl;
00108     if (in.discrete_field_.size() > 0) {
00109
00110     }
00111   }
00112   return stream;
00113 }
00114 }
00115
00116 mtk::UniStgGrid3D mtk::UniStgGrid3D::operator=(const
      mtk::UniStgGrid3D &in) {
00117
00118   UniStgGrid3D out(in);
00119
00120   return out;
00121 }
00122
00123 mtk::UniStgGrid3D::UniStgGrid3D():
00124     discrete_domain_x_(),
00125     discrete_domain_y_(),
00126     discrete_domain_z_(),
00127     discrete_field_(),
00128     nature_(),
00129     west_bndy_(),
00130     east_bndy_(),
00131     num_cells_x_(),
00132     delta_x_(),
00133     south_bndy_(),
00134     north_bndy_(),
00135     num_cells_y_(),
00136     delta_y_(),
00137     bottom_bndy_(),
00138     top_bndy_(),
00139     num_cells_z_(),
00140     delta_z_() {}
00141
00142 mtk::UniStgGrid3D::UniStgGrid3D(const
      UniStgGrid3D &grid):
00143     nature_(grid.nature_),
00144     west_bndy_(grid.west_bndy_),
00145     east_bndy_(grid.east_bndy_),
00146     num_cells_x_(grid.num_cells_x_),
00147     delta_x_(grid.delta_x_),
00148     south_bndy_(grid.south_bndy_),
00149     north_bndy_(grid.north_bndy_),
00150     num_cells_y_(grid.num_cells_y_),
00151     delta_y_(grid.delta_y_),
00152     bottom_bndy_(grid.bottom_bndy_),
00153     top_bndy_(grid.top_bndy_),
00154     num_cells_z_(grid.num_cells_z_),
00155     delta_z_(grid.delta_z_) {
00156
00157     std::copy(grid.discrete_domain_x_.begin(),
00158               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00159               discrete_domain_x_.begin());
00160
00161     std::copy(grid.discrete_domain_y_.begin(),
00162               grid.discrete_domain_y_.begin() + grid.
      discrete_domain_y_.size(),
00163               discrete_domain_y_.begin());
00164
00165     std::copy(grid.discrete_domain_z_.begin(),
00166               grid.discrete_domain_z_.begin() + grid.
      discrete_domain_z_.size(),
00167               discrete_domain_z_.begin());
00168
00169     std::copy(grid.discrete_field_.begin(),
00170               grid.discrete_field_.begin() + grid.discrete_field_.size(),
00171               discrete_field_.begin());
```

```
00172 }
00173
00174 mtk::UniStgGrid3D::UniStgGrid3D(const Real &west_bndy,
00175                                 const Real &east_bndy,
00176                                 const int &num_cells_x,
00177                                 const Real &south_bndy,
00178                                 const Real &north_bndy,
00179                                 const int &num_cells_y,
00180                                 const Real &bottom_bndy,
00181                                 const Real &top_bndy,
00182                                 const int &num_cells_z,
00183                                 const mtk::FieldNature &nature) {
00184
00185   #ifdef MTK_PERFORM_PREVENTIONS
00186   mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00187   mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00188   mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00189   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00190   mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00191   mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00192   mtk::Tools::Prevent(north_bndy <= south_bndy,
00193                       __FILE__, __LINE__, __func__);
00194   mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00195   mtk::Tools::Prevent(bottom_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00196   mtk::Tools::Prevent(top_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00197   mtk::Tools::Prevent(top_bndy <= bottom_bndy,
00198                       __FILE__, __LINE__, __func__);
00199   mtk::Tools::Prevent(num_cells_z < 0, __FILE__, __LINE__, __func__);
00200   #endif
00201
00202   nature_ = nature;
00203
00204   west_bndy_ = west_bndy;
00205   east_bndy_ = east_bndy;
00206   num_cells_x_ = num_cells_x;
00207
00208   south_bndy_ = south_bndy;
00209   north_bndy_ = north_bndy;
00210   num_cells_y_ = num_cells_y;
00211
00212   bottom_bndy_ = bottom_bndy;
00213   top_bndy_ = top_bndy;
00214   num_cells_z_ = num_cells_z;
00215
00216   delta_x_ = (east_bndy_ - west_bndy_)/((mtk::Real) num_cells_x);
00217   delta_y_ = (north_bndy_ - south_bndy_)/((mtk::Real) num_cells_y);
00218   delta_z_ = (top_bndy_ - bottom_bndy_)/((mtk::Real) num_cells_z);
00219 }
00220
00221 mtk::UniStgGrid3D::~UniStgGrid3D() {}
00222
00223 mtk::FieldNature mtk::UniStgGrid3D::nature() const {
00224
00225   return nature_;
00226 }
00227
00228 mtk::Real mtk::UniStgGrid3D::west_bndy() const {
00229
00230   return west_bndy_;
00231 }
00232
00233 mtk::Real mtk::UniStgGrid3D::east_bndy() const {
00234
00235   return east_bndy_;
00236 }
00237
00238 int mtk::UniStgGrid3D::num_cells_x() const {
00239
00240   return num_cells_x_;
00241 }
00242
00243 mtk::Real mtk::UniStgGrid3D::delta_x() const {
00244
00245   return delta_x_;
00246 }
00247
00248 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_x() const
    {
00249
00250   return discrete_domain_x_.data();
00251 }
```

```
00252
00253 mtk::Real mtk::UniStgGrid3D::south_bndy() const {
00254
00255   return south_bndy_;
00256 }
00257
00258 mtk::Real mtk::UniStgGrid3D::north_bndy() const {
00259
00260   return north_bndy_;
00261 }
00262
00263 int mtk::UniStgGrid3D::num_cells_y() const {
00264
00265   return num_cells_y_;
00266 }
00267
00268 mtk::Real mtk::UniStgGrid3D::delta_y() const {
00269
00270   return delta_y_;
00271 }
00272
00273 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_y() const
     {
00274
00275   return discrete_domain_y_.data();
00276 }
00277
00278 mtk::Real mtk::UniStgGrid3D::bottom_bndy() const {
00279
00280   return bottom_bndy_;
00281 }
00282
00283 mtk::Real mtk::UniStgGrid3D::top_bndy() const {
00284
00285   return top_bndy_;
00286 }
00287
00288 int mtk::UniStgGrid3D::num_cells_z() const {
00289
00290   return num_cells_z_;
00291 }
00292
00293 mtk::Real mtk::UniStgGrid3D::delta_z() const {
00294
00295   return delta_z_;
00296 }
00297
00298 const mtk::Real* mtk::UniStgGrid3D::discrete_domain_z() const
     {
00299
00300   return discrete_domain_z_.data();
00301 }
00302
00303 mtk::Real* mtk::UniStgGrid3D::discrete_field() {
00304
00305   return discrete_field_.data();
00306 }
00307
00308 bool mtk::UniStgGrid3D::Bound() const {
00309
00310   return discrete_field_.size() != 0;
00311 }
00312
00313 int mtk::UniStgGrid3D::Size() const {
00314
00315   return discrete_field_.size();
00316 }
00317
00318 void mtk::UniStgGrid3D::BindScalarField(
00319     mtk::Real (*ScalarField)(const mtk::Real &xx,
00320                              const mtk::Real &yy,
00321                              const mtk::Real &zz)) {
00322
00323   #ifdef MTK_PERFORM_PREVENTIONS
00324   mtk::Tools::Prevent(nature_ != mtk::FieldNature::SCALAR,
     __FILE__, __LINE__,
00325 __func__);
00326   #endif
00327
00329
00330   discrete_domain_x_.reserve(num_cells_x_ + 2);
```

```
00331
00332   discrete_domain_x_.push_back(west_bndy_);
00333   #ifdef MTK_PRECISION_DOUBLE
00334   auto first_center = west_bndy_ + delta_x_/2.0;
00335   #else
00336   auto first_center = west_bndy_ + delta_x_/2.0f;
00337   #endif
00338   discrete_domain_x_.push_back(first_center);
00339   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00340     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00341   }
00342   discrete_domain_x_.push_back(east_bndy_);
00343
00345
00346   discrete_domain_y_.reserve(num_cells_y_ + 2);
00347
00348   discrete_domain_y_.push_back(south_bndy_);
00349   #ifdef MTK_PRECISION_DOUBLE
00350   first_center = south_bndy_ + delta_x_/2.0;
00351   #else
00352   first_center = south_bndy_ + delta_x_/2.0f;
00353   #endif
00354   discrete_domain_y_.push_back(first_center);
00355   for (auto ii = 1; ii < num_cells_y_; ++ii) {
00356     discrete_domain_y_.push_back(first_center + ii*delta_y_);
00357   }
00358   discrete_domain_y_.push_back(north_bndy_);
00359
00361
00362   discrete_domain_z_.reserve(num_cells_z_ + 2);
00363
00364   discrete_domain_z_.push_back(bottom_bndy_);
00365   first_center = bottom_bndy_ + delta_z_/mtk::kTwo;
00366   discrete_domain_z_.push_back(first_center);
00367   for (auto ii = 1; ii < num_cells_z_; ++ii) {
00368     discrete_domain_z_.push_back(first_center + ii*delta_z_);
00369   }
00370   discrete_domain_z_.push_back(top_bndy_);
00371
00373
00374   int aux{(num_cells_x_ + 2)*(num_cells_y_ + 2)*(num_cells_z_ + 2)};
00375
00376   discrete_field_.reserve(aux);
00377
00378   for (int kk = 0; kk < num_cells_z_ + 2; ++kk) {
00379     for (int ii = 0; ii < num_cells_y_ + 2; ++ii) {
00380       for (int jj = 0; jj < num_cells_x_ + 2; ++jj) {
00381         #if MTK_VERBOSE_LEVEL > 6
00382         std::cout << "At z = " << discrete_domain_z_[kk] << ": Pushing value"
00383           " for x = " << discrete_domain_x_[jj] << " y = " <<
00384           discrete_domain_y_[ii] << std::endl;
00385         #endif
00386         discrete_field_.push_back(ScalarField(discrete_domain_x_[jj],
00387                                               discrete_domain_y_[ii],
00388                                               discrete_domain_z_[kk]));
00389       }
00390     }
00391   }
00392 }
00393
00394 void mtk::UniStgGrid3D::BindVectorFieldPComponent(
00395   mtk::Real (*VectorField)(const mtk::Real &xx,
00396                            const mtk::Real &yy,
00397                            const mtk::Real &zz)) {
00398
00399 }
00400
00401 void mtk::UniStgGrid3D::BindVectorFieldQComponent(
00402   mtk::Real (*VectorField)(const mtk::Real &xx,
00403                            const mtk::Real &yy,
00404                            const mtk::Real &zz)) {
00405
00406 }
00407
00408 void mtk::UniStgGrid3D::BindVectorFieldRComponent(
00409   mtk::Real (*VectorField)(const mtk::Real &xx,
00410                            const mtk::Real &yy,
00411                            const mtk::Real &zz)) {
00412
00413 }
00414
```

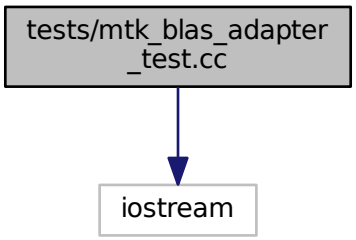
```
00415 void mtk::UniStgGrid3D::BindVectorField(
00416   mtk::Real (*VectorFieldPComponent)(const mtk::Real &xx,
00417                                      const mtk::Real &yy,
00418                                      const mtk::Real &zz),
00419   mtk::Real (*VectorFieldQComponent)(const mtk::Real &xx,
00420                                      const mtk::Real &yy,
00421                                      const mtk::Real &zz),
00422   mtk::Real (*VectorFieldRComponent)(const mtk::Real &xx,
00423                                      const mtk::Real &yy,
00424                                      const mtk::Real &zz)) {
00425
00426   #ifdef MTK_PERFORM_PREVENTIONS
00427   mtk::Tools::Prevent(nature_ != mtk::FieldNature::VECTOR,
      __FILE__, __LINE__,
00428 __func__);
00429   #endif
00430
00431   BindVectorFieldPComponent(VectorFieldPComponent);
00432   BindVectorFieldQComponent(VectorFieldQComponent);
00433 }
00434
00435 bool mtk::UniStgGrid3D::WriteToFile(std::string filename,
00436                                     std::string space_name_x,
00437                                     std::string space_name_y,
00438                                     std::string space_name_z,
00439                                     std::string field_name) const {
00440
00441   std::ofstream output_dat_file;  // Output file.
00442
00443   output_dat_file.open(filename);
00444
00445   if (!output_dat_file.is_open()) {
00446     return false;
00447   }
00448
00449   if (nature_ == mtk::FieldNature::SCALAR) {
00450     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00451       space_name_z << ' ' << field_name << std::endl;
00452
00453   int idx{};
00454   for (int kk = 0; kk < num_cells_z_ + 2; ++kk) {
00455     for (int ii = 0; ii < num_cells_y_ + 2; ++ii) {
00456       for (int jj = 0; jj < num_cells_x_ + 2; ++jj) {
00457         output_dat_file << discrete_domain_x_[jj] << ' ' <<
00458           discrete_domain_y_[ii] << ' ' << discrete_domain_z_[kk] << ' ' <<
00459           discrete_field_[idx] << std::endl;
00460         idx++;
00461       }
00462     }
00463   }
00464
00465   } else {
00466     output_dat_file << "# " << space_name_x <<  ' ' << space_name_y << ' ' <<
00467       space_name_z << ' ' << field_name << std::endl;
00468
00469   }
00470
00471   output_dat_file.close();
00472
00473   return true;
00474 }
```

18.127 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 ()

18.127.1 Detailed Description

Author

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

Definition in file mtk_blas_adapter_test.cc.

18.127.2 Function Documentation

18.127.2.1 int main ( )

Definition at line 109 of file mtk_blas_adapter_test.cc.

18.128 mtk_blas_adapter_test.cc

```
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

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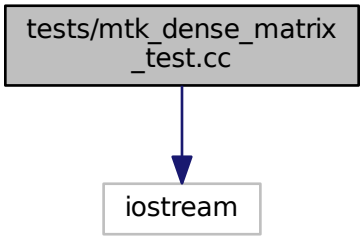
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestRealDenseMM() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   int rr = 2;
00065   int cc = 3;
00066
00067   mtk::DenseMatrix aa(rr,cc);
00068
00069   aa.SetValue(0,0,1.0);
00070   aa.SetValue(0,1,2.0);
00071   aa.SetValue(0,2,3.0);
00072   aa.SetValue(1,0,4.0);
00073   aa.SetValue(1,1,5.0);
00074   aa.SetValue(1,2,6.0);
00075
00076   mtk::DenseMatrix bb(cc,rr);
00077
00078   bb.SetValue(0,0,7.0);
00079   bb.SetValue(0,1,8.0);
00080   bb.SetValue(1,0,9.0);
00081   bb.SetValue(1,1,10.0);
00082   bb.SetValue(2,0,11.0);
00083   bb.SetValue(2,1,12.0);
00084
00085   mtk::DenseMatrix pp = mtk::BLASAdapter::RealDenseMM(aa,bb);
00086
00087   mtk::DenseMatrix ff(rr,rr);
00088
00089   ff.SetValue(0,0,58.0);
00090   ff.SetValue(0,1,64.00);
00091   ff.SetValue(1,0,139.0);
00092   ff.SetValue(1,1,154.0);
00093
00094   mtk::Tools::EndUnitTestNo(1);
00095   mtk::Tools::Assert(pp == ff);
00096 }
00097
00098 int main () {
00099
00100   std::cout << "Testing mtk::BLASAdapter class." << std::endl;
00101
00102   TestRealDenseMM();
00103 }
00104
```

```
00105 #else
00106 #include <iostream>
00107 using std::cout;
00108 using std::endl;
00109 int main () {
00110   cout << "This code HAS to be compiled with support for C++11." << endl;
00111   cout << "Exiting..." << endl;
00112 }
00113 #endif
```

18.129 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 ()

18.129.1 Detailed Description

Author

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

Definition in file mtk_dense_matrix_test.cc.

18.129.2 Function Documentation

18.129.2.1 int main ( )

Definition at line 330 of file mtk_dense_matrix_test.cc.

18.130 mtk_dense_matrix_test.cc

```
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
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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);
```

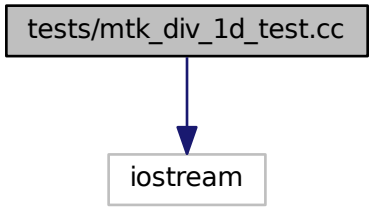
```
00247   rr.SetValue(2,9,5.0);
00248
00249   rr.SetValue(3,0,0.0);
00250   rr.SetValue(3,1,0.0);
00251   rr.SetValue(3,2,0.0);
00252   rr.SetValue(3,3,0.0);
00253   rr.SetValue(3,4,0.0);
00254   rr.SetValue(3,5,6.0);
00255   rr.SetValue(3,6,7.0);
00256   rr.SetValue(3,7,8.0);
00257   rr.SetValue(3,8,9.0);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

18.131 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 ()

18.131.1 Detailed Description

Author

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

Definition in file mtk_div_1d_test.cc.

18.131.2 Function Documentation

18.131.2.1 int main ( )

Definition at line 288 of file mtk_div_1d_test.cc.

18.132 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
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Div1D div2;
00065
00066   bool assertion = div2.ConstructDiv1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00070   }
00071
00072   mtk::Tools::EndUnitTestNo(1);
00073   mtk::Tools::Assert(assertion);
00074 }
00075
00076 void TestDefaultConstructorFactoryMethodFourthOrder() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Div1D div4;
00081
00082   bool assertion = div4.ConstructDiv1D(4);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(2);
```

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

```
00170 }
00171
00172 void TestSecondOrderReturnAsDenseMatrixWithGrid() {
00173
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);
```

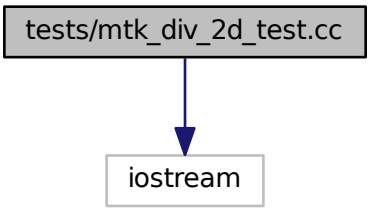
```
00251
00252   if (!assertion) {
00253     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00254   }
00255
00256   std::cout << div4 << std::endl;
00257
00258   mtk::UniStgGrid1D grid(0.0, 1.0, 11);
00259
00260   std::cout << grid << std::endl;
00261
00262   mtk::DenseMatrix 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
```

18.133 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 ()

18.133.1 Detailed Description

Author

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

Definition in file mtk_div_2d_test.cc.

18.133.2 Function Documentation

18.133.2.1 int main ( )

Definition at line 139 of file mtk_div_2d_test.cc.

18.134 mtk_div_2d_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
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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
```

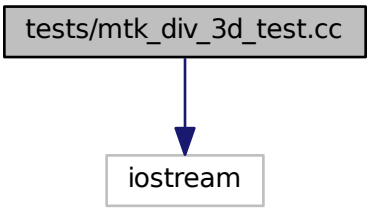
```
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Div2D dd;
00068
00069   mtk::Real aa = 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
```

18.135 tests/mtk_div_3d_test.cc File Reference

Test file for the mtk::Div3D class.

`#include <iostream>`
Include dependency graph for mtk_div_3d_test.cc:



Functions

- int main ()

18.135.1 Detailed Description

Author

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

Definition in file mtk_div_3d_test.cc.

18.135.2 Function Documentation

18.135.2.1 int main ( )

Definition at line 145 of file mtk_div_3d_test.cc.

18.136 mtk_div_3d_test.cc

```
00001
```

```
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <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::Div3D div;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073   mtk::Real ee = 0.0;
00074   mtk::Real ff = 1.0;
00075
00076   int nn = 5;
00077   int mm = 5;
00078   int oo = 5;
00079
00080   mtk::UniStgGrid3D divg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00081
00082   bool assertion = div.ConstructDiv3D(divg);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(1);
```

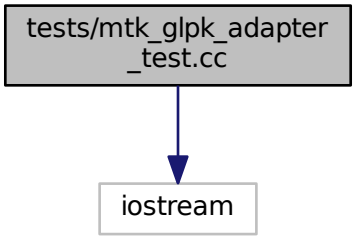
```
00089   mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestReturnAsDenseMatrixWriteToFile() {
00093
00094   mtk::Tools::BeginUnitTestNo(2);
00095
00096   mtk::Div3D div;
00097
00098   mtk::Real aa = 0.0;
00099   mtk::Real bb = 1.0;
00100   mtk::Real cc = 0.0;
00101   mtk::Real dd = 1.0;
00102   mtk::Real ee = 0.0;
00103   mtk::Real ff = 1.0;
00104
00105   int nn = 5;
00106   int mm = 5;
00107   int oo = 5;
00108
00109   mtk::UniStgGrid3D divg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00110
00111   bool assertion = div.ConstructDiv3D(divg);
00112
00113   if (!assertion) {
00114     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00115   }
00116
00117   mtk::DenseMatrix divm(div.ReturnAsDenseMatrix());
00118
00119   assertion = assertion && (divm.num_rows() != mtk::kZero);
00120
00121   std::cout << divm << std::endl;
00122
00123   assertion = assertion && divm.WriteToFile("mtk_div_3d_test_02.dat");
00124
00125   if(!assertion) {
00126     std::cerr << "Error writing to file." << std::endl;
00127   }
00128
00129   mtk::Tools::EndUnitTestNo(2);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 int main () {
00134
00135   std::cout << "Testing mtk::Div3D class." << std::endl;
00136
00137   TestDefaultConstructorFactory();
00138   TestReturnAsDenseMatrixWriteToFile();
00139 }
00140
00141 #else
00142 #include <iostream>
00143 using std::cout;
00144 using std::endl;
00145 int main () {
00146   cout << "This code HAS to be compiled with support for C++11." << endl;
00147   cout << "Exiting..." << endl;
00148 }
00149 #endif
```

18.137 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 ()

18.137.1 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.

18.137.2 Function Documentation

18.137.2.1 int main ( )

Definition at line 81 of file mtk_glpk_adapter_test.cc.

18.138 mtk_glpk_adapter_test.cc

```
00001
00010 /*
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00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
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.
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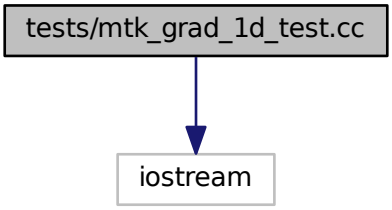
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072   std::cout << "Testing mtk::GLPKAdapter class." << std::endl;
00073
00074   Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082   cout << "This code HAS to be compiled with support for C++11." << endl;
00083   cout << "Exiting..." << endl;
00084 }
00085 #endif
```

18.139 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 ()

18.139.1 Detailed Description

Author

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

Definition in file mtk_grad_1d_test.cc.

18.139.2 Function Documentation

18.139.2.1 int main ( )

Definition at line 319 of file mtk_grad_1d_test.cc.

18.140 mtk_grad_1d_test.cc

```
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00008 /*
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00013 are permitted provided that the following conditions are met:
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
```

```
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactoryMethodDefault() {
00061
00062   mtk::Tools::BeginUnitTestNo(1);
00063
00064   mtk::Grad1D grad2;
00065
00066   bool assertion = grad2.ConstructGrad1D();
00067
00068   if (!assertion) {
00069     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00070
00071   }
00072
00073   std::cout << grad2 << std::endl;
00074
00075   mtk::Tools::EndUnitTestNo(1);
00076   mtk::Tools::Assert(assertion);
00077 }
00078
00079 void TestDefaultConstructorFactoryMethodFourthOrder() {
00080
00081   mtk::Tools::BeginUnitTestNo(2);
00082
00083   mtk::Grad1D grad4;
00084
00085   bool assertion = grad4.ConstructGrad1D(4);
00086
00087   if (!assertion) {
00088     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00089   }
00090
00091   std::cout << grad4 << std::endl;
00092
00093   mtk::Tools::EndUnitTestNo(2);
00094   mtk::Tools::Assert(assertion);
00095 }
00096
00097 void TestDefaultConstructorFactoryMethodSixthOrder() {
00098
00099   mtk::Tools::BeginUnitTestNo(3);
00100
00101   mtk::Grad1D grad6;
00102
00103   bool assertion = grad6.ConstructGrad1D(6);
00104
00105   if (!assertion) {
```

```
00106     std::cerr << "Mimetic grad (6th order) could not be built." << std::endl;
00107   }
00108
00109   std::cout << grad6 << std::endl;
00110
00111   mtk::Tools::EndUnitTestNo(3);
00112   mtk::Tools::Assert(assertion);
00113 }
00114
00115 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00116
00117   mtk::Tools::BeginUnitTestNo(4);
00118
00119   mtk::Grad1D grad8;
00120
00121   bool assertion = grad8.ConstructGrad1D(8);
00122
00123   if (!assertion) {
00124     std::cerr << "Mimetic grad (8th order) could not be built." << std::endl;
00125   }
00126
00127   std::cout << grad8 << std::endl;
00128
00129   mtk::Tools::EndUnitTestNo(4);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00134
00135   mtk::Tools::BeginUnitTestNo(5);
00136
00137   mtk::Grad1D grad10;
00138
00139   bool assertion = grad10.ConstructGrad1D(10);
00140
00141   if (!assertion) {
00142     std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00143   }
00144
00145   std::cout << grad10 << std::endl;
00146
00147   mtk::Tools::EndUnitTestNo(5);
00148   mtk::Tools::Assert(assertion);
00149 }
00150
00151 void TestReturnAsDenseMatrixWithGrid() {
00152
00153   mtk::Tools::BeginUnitTestNo(6);
00154
00155   mtk::Grad1D grad2;
00156
00157   bool assertion = grad2.ConstructGrad1D();
00158
00159   if (!assertion) {
00160     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00161   }
00162
00163   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00164
00165   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00166
00167   int rr{6};
00168   int cc{7};
00169
00170   mtk::DenseMatrix ref(rr, cc);
00171
00172   // Row 1.
00173   ref.SetValue(0,0,-13.3333);
00174   ref.SetValue(0,1,15);
00175   ref.SetValue(0,2,-1.66667);
00176   ref.SetValue(0,3,0.0);
00177   ref.SetValue(0,4,0.0);
00178   ref.SetValue(0,5,0.0);
00179   ref.SetValue(0,6,0.0);
00180
00181   // Row 2.
00182   ref.SetValue(1,0,0.0);
00183   ref.SetValue(1,1,-5.0);
00184   ref.SetValue(1,2,5.0);
00185   ref.SetValue(1,3,0.0);
00186   ref.SetValue(1,4,0.0);
```

```
00187   ref.SetValue(1,5,0.0);
00188   ref.SetValue(1,6,0.0);
00189
00190   // Row 3.
00191   ref.SetValue(2,0,0.0);
00192   ref.SetValue(2,1,0.0);
00193   ref.SetValue(2,2,-5.0);
00194   ref.SetValue(2,3,5.0);
00195   ref.SetValue(2,4,0.0);
00196   ref.SetValue(2,5,0.0);
00197   ref.SetValue(2,6,0.0);
00198
00199   // Row 4.
00200   ref.SetValue(3,0,0.0);
00201   ref.SetValue(3,1,0.0);
00202   ref.SetValue(3,2,0.0);
00203   ref.SetValue(3,3,-5.0);
00204   ref.SetValue(3,4,5.0);
00205   ref.SetValue(3,5,0.0);
00206   ref.SetValue(3,6,0.0);
00207
00208   // Row 5.
00209   ref.SetValue(4,0,0.0);
00210   ref.SetValue(4,1,0.0);
00211   ref.SetValue(4,2,0.0);
00212   ref.SetValue(4,3,0.0);
00213   ref.SetValue(4,4,-5.0);
00214   ref.SetValue(4,5,5.0);
00215   ref.SetValue(4,6,0.0);
00216
00217   // Row 6.
00218   ref.SetValue(5,0,0.0);
00219   ref.SetValue(5,1,0.0);
00220   ref.SetValue(5,2,0.0);
00221   ref.SetValue(5,3,0.0);
00222   ref.SetValue(5,4,1.66667);
00223   ref.SetValue(5,5,-15.0);
00224   ref.SetValue(5,6,13.3333);
00225
00226   mtk::Tools::EndUnitTestNo(6);
00227   mtk::Tools::Assert(grad2m == ref);
00228 }
00229
00230 void TestReturnAsDimensionlessDenseMatrix() {
00231
00232   mtk::Tools::BeginUnitTestNo(7);
00233
00234   mtk::Grad1D grad4;
00235
00236   bool assertion = grad4.ConstructGrad1D(4);
00237
00238   if (!assertion) {
00239     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00240   }
00241
00242   mtk::DenseMatrix grad4m(grad4.ReturnAsDimensionlessDenseMatrix
      (10));
00243
00244   std::cout << grad4m << std::endl;
00245
00246   mtk::Tools::EndUnitTestNo(7);
00247   mtk::Tools::Assert(assertion);
00248 }
00249
00250 void TestWriteToFile() {
00251
00252   mtk::Tools::BeginUnitTestNo(8);
00253
00254   mtk::Grad1D grad2;
00255
00256   bool assertion = grad2.ConstructGrad1D();
00257
00258   if (!assertion) {
00259     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00260   }
00261
00262   mtk::UniStgGrid1D grid(0.0, 1.0, 50);
00263
00264   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00265
00266   std::cout << grad2m << std::endl;
```

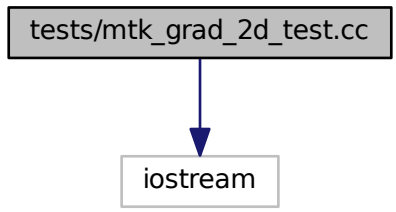
```
00267
00268   assertion = assertion && grad2m.WriteToFile("mtk_grad_1d_test_08.dat");
00269
00270   if(!assertion) {
00271     std::cerr << "Error writing to file." << std::endl;
00272   }
00273
00274   mtk::Tools::EndUnitTestNo(8);
00275   mtk::Tools::Assert(assertion);
00276 }
00277
00278 void TestMimBndy() {
00279
00280   mtk::Tools::BeginUnitTestNo(9);
00281
00282   mtk::Grad1D grad2;
00283
00284   bool assertion = grad2.ConstructGrad1D();
00285
00286   if (!assertion) {
00287     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00288   }
00289
00290   std::cout << grad2 << std::endl;
00291
00292   mtk::DenseMatrix grad2m(grad2.mim_bndy());
00293
00294   std::cout << grad2m << std::endl;
00295
00296   mtk::Tools::EndUnitTestNo(9);
00297   mtk::Tools::Assert(assertion);
00298 }
00299
00300 int main () {
00301
00302   std::cout << "Testing mtk::Grad1D class." << std::endl;
00303
00304   TestDefaultConstructorFactoryMethodDefault();
00305   TestDefaultConstructorFactoryMethodFourthOrder();
00306   TestDefaultConstructorFactoryMethodSixthOrder();
00307   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00308   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00309   TestReturnAsDenseMatrixWithGrid();
00310   TestReturnAsDimensionlessDenseMatrix();
00311   TestWriteToFile();
00312   TestMimBndy();
00313 }
00314
00315 #else
00316 #include <iostream>
00317 using std::cout;
00318 using std::endl;
00319 int main () {
00320   cout << "This code HAS to be compiled with support for C++11." << endl;
00321   cout << "Exiting..." << endl;
00322 }
00323 #endif
```

18.141 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 ()

18.141.1 Detailed Description

Author

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

Definition in file mtk_grad_2d_test.cc.

18.141.2 Function Documentation

18.141.2.1 int main ( )

Definition at line 139 of file mtk_grad_2d_test.cc.

18.142 mtk_grad_2d_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
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00014
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
```

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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::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::FieldNature::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::FieldNature::VECTOR);
```

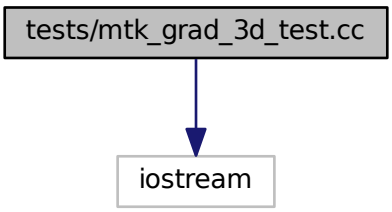
```
00104
00105   bool assertion = gg.ConstructGrad2D(ggg);
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (ggm.num_rows() != 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
```

18.143 tests/mtk_grad_3d_test.cc File Reference

Test file for the mtk::Grad3D class.

`#include <iostream>`

Include dependency graph for mtk_grad_3d_test.cc:



Functions

- int main ()

18.143.1 Detailed Description

Author

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

Definition in file mtk_grad_3d_test.cc.

18.143.2 Function Documentation

18.143.2.1 int main ( )

Definition at line 147 of file mtk_grad_3d_test.cc.

18.144 mtk_grad_3d_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
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00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
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00038 third parties. The copyright holders disclaim any liability to any recipient for
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00040 parties intellectual property rights.
00041
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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
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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
```

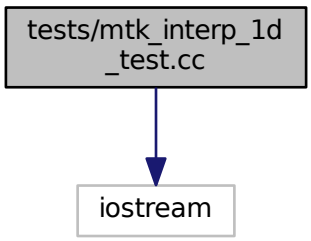
```
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Grad3D gg;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073   mtk::Real ee = 0.0;
00074   mtk::Real ff = 1.0;
00075
00076   int nn = 5;
00077   int mm = 5;
00078   int oo = 5;
00079
00080   mtk::UniStgGrid3D ggg(aa, bb, nn, cc, dd, mm, ee, ff, oo,
00081 mtk::FieldNature::VECTOR);
00082
00083   bool assertion = gg.ConstructGrad3D(ggg);
00084
00085   if (!assertion) {
00086     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00087   }
00088
00089   mtk::Tools::EndUnitTestNo(1);
00090   mtk::Tools::Assert(assertion);
00091 }
00092
00093 void TestReturnAsDenseMatrixWriteToFile() {
00094
00095   mtk::Tools::BeginUnitTestNo(2);
00096
00097   mtk::Grad3D gg;
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   mtk::Real ee = 0.0;
00104   mtk::Real ff = 1.0;
00105
00106   int nn = 5;
00107   int mm = 5;
00108   int oo = 5;
00109
00110   mtk::UniStgGrid3D ggg(aa, bb, nn, cc, dd, mm, ee, ff, oo,
00111 mtk::FieldNature::VECTOR);
00112
00113   bool assertion = gg.ConstructGrad3D(ggg);
00114
00115   if (!assertion) {
00116     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00117   }
00118
00119   mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00120
00121   assertion = assertion && (ggm.num_rows() != mtk::kZero);
00122
00123   std::cout << ggm << std::endl;
00124
00125   assertion = assertion && ggm.WriteToFile("mtk_grad_3d_test_02.dat");
00126
00127   if(!assertion) {
00128     std::cerr << "Error writing to file." << std::endl;
00129   }
00130
00131   mtk::Tools::EndUnitTestNo(2);
00132   mtk::Tools::Assert(assertion);
00133 }
00134
```

```
00135 int main () {
00136
00137   std::cout << "Testing mtk::Grad2D class." << std::endl;
00138
00139   TestDefaultConstructorFactory();
00140   TestReturnAsDenseMatrixWriteToFile();
00141 }
00142
00143 #else
00144 #include <iostream>
00145 using std::cout;
00146 using std::endl;
00147 int main () {
00148   cout << "This code HAS to be compiled with support for C++11." << endl;
00149   cout << "Exiting..." << endl;
00150 }
00151 #endif
```

18.145 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 ()

18.145.1 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.

18.145.2 Function Documentation

18.145.2.1 int main ( )

Definition at line 113 of file mtk_interp_1d_test.cc.

18.146 mtk_interp_1d_test.cc

```
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00012 University. All rights reserved.
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00015 are permitted provided that the following conditions are met:
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064   mtk::Tools::BeginUnitTestNo(1);
00065
00066   mtk::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() {
```

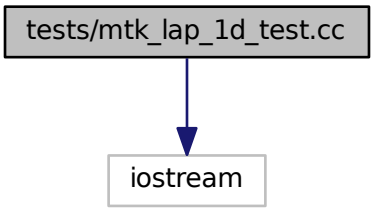
```
00079
00080   mtk::Tools::BeginUnitTestNo(2);
00081
00082   mtk::Interp1D inter;
00083
00084   bool assertion = inter.ConstructInterp1D();
00085
00086   if (!assertion) {
00087     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00088   }
00089
00090   mtk::UniStgGrid1D 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
```

18.147 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 ()

18.147.1 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.

18.147.2 Function Documentation

18.147.2.1 int main ( )

Definition at line 193 of file mtk_lap_1d_test.cc.

18.148 mtk_lap_1d_test.cc

```
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00015 are permitted provided that the following conditions are met:
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00026 3. Redistributions in binary form must reproduce the above copyright notice,
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
```

```
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064   mtk::Tools::BeginUnitTestNo(1);
00065
00066   mtk::Lap1D lap2;
00067
00068   bool assertion = lap2.ConstructLap1D();
00069
00070   if (!assertion) {
00071     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00072   }
00073
00074   mtk::Tools::EndUnitTestNo(1);
00075   mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestDefaultConstructorFactoryMethodFourthOrder() {
00079
00080   mtk::Tools::BeginUnitTestNo(2);
00081
00082   mtk::Lap1D lap4;
00083
00084   bool assertion = lap4.ConstructLap1D(4);
00085
00086   if (!assertion) {
00087     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00088   }
00089
00090   mtk::Tools::EndUnitTestNo(2);
00091   mtk::Tools::Assert(assertion);
00092 }
00093
00094 void TestDefaultConstructorFactoryMethodSixthOrder() {
00095
00096   mtk::Tools::BeginUnitTestNo(3);
00097
00098   mtk::Lap1D lap6;
00099
00100   bool assertion = lap6.ConstructLap1D(6);
00101
00102   if (!assertion) {
00103     std::cerr << "Mimetic lap (6th order) could not be built." << std::endl;
00104   }
00105
00106   mtk::Tools::EndUnitTestNo(3);
00107   mtk::Tools::Assert(assertion);
00108 }
00109
00110 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00111
00112   mtk::Tools::BeginUnitTestNo(4);
00113
00114   mtk::Lap1D lap8;
00115
00116   bool assertion = lap8.ConstructLap1D(8);
00117
00118   if (!assertion) {
00119     std::cerr << "Mimetic lap (8th order) could not be built." << std::endl;
00120   }
00121
00122   mtk::Tools::EndUnitTestNo(4);
00123 }
00124
00125 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00126
00127   mtk::Tools::BeginUnitTestNo(5);
00128
00129   mtk::Lap1D lap10;
00130
00131   bool assertion = lap10.ConstructLap1D(10);
00132
00133   if (!assertion) {
00134     std::cerr << "Mimetic lap (10th order) could not be built." << std::endl;
00135   }
00136
00137   mtk::Tools::EndUnitTestNo(5);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
```

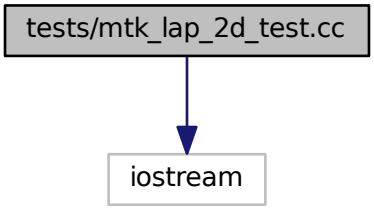
```
00142   mtk::Tools::BeginUnitTestNo(6);
00143
00144   mtk::Lap1D lap12;
00145
00146   bool assertion = lap12.ConstructLap1D(12);
00147
00148   if (!assertion) {
00149     std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00150   }
00151
00152   mtk::Tools::EndUnitTestNo(6);
00153 }
00154
00155 void TestReturnAsDenseMatrix() {
00156
00157   mtk::Tools::BeginUnitTestNo(8);
00158
00159   mtk::Lap1D lap4;
00160
00161   bool assertion = lap4.ConstructLap1D(4);
00162
00163   if (!assertion) {
00164     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00165   }
00166
00167   mtk::UniStgGrid1D aux(0.0, 1.0, 11);
00168
00169   mtk::DenseMatrix lap4_m(lap4.ReturnAsDenseMatrix(aux));
00170
00171   assertion = assertion &&
00172       abs(lap4_m.GetValue(1, 0) - 385.133) < mtk::kDefaultTolerance &&
00173       abs(lap4_m.GetValue(11, 12) - 385.133) < mtk::kDefaultTolerance;
00174   mtk::Tools::EndUnitTestNo(8);
00175   mtk::Tools::Assert(assertion);
00176 }
00177
00178 int main () {
00179
00180   std::cout << "Testing MTK 1D Laplacian" << std::endl;
00181
00182   TestDefaultConstructorFactoryMethodDefault();
00183   TestDefaultConstructorFactoryMethodFourthOrder();
00184   TestDefaultConstructorFactoryMethodSixthOrder();
00185   TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00186   TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00187   TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00188   TestReturnAsDenseMatrix();
00189 }
00190
00191 #else
00192 #include <iostream>
00193 int main () {
00194   std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00195   std::cout << "Exiting..." << std::endl;
00196 }
00197 #endif
```

18.149 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 ()

18.149.1 Detailed Description

Author

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

Definition in file mtk_lap_2d_test.cc.

18.149.2 Function Documentation

18.149.2.1 int main ( )

Definition at line 139 of file mtk_lap_2d_test.cc.

18.150 mtk_lap_2d_test.cc

```
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00010 University. All rights reserved.
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Lap2D ll;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073
00074   int nn = 5;
00075   int mm = 5;
00076
00077   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00078
00079   bool assertion = ll.ConstructLap2D(llg);
00080
00081   if (!assertion) {
00082     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00083   }
00084
00085   mtk::Tools::EndUnitTestNo(1);
00086   mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091   mtk::Tools::BeginUnitTestNo(2);
00092
00093   mtk::Lap2D ll;
00094
00095   mtk::Real aa = 0.0;
00096   mtk::Real bb = 1.0;
00097   mtk::Real cc = 0.0;
00098   mtk::Real dd = 1.0;
00099
00100   int nn = 5;
00101   int mm = 5;
00102
00103   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00104
00105   bool assertion = ll.ConstructLap2D(llg);
```

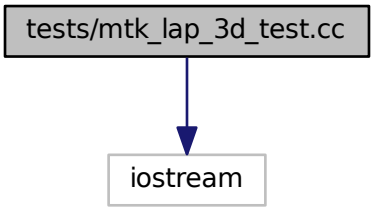
```
00106
00107   if (!assertion) {
00108     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00109   }
00110
00111   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00112
00113   assertion = assertion && (llm.num_rows() != 0);
00114
00115   std::cout << llm << std::endl;
00116
00117   assertion = assertion && llm.WriteToFile("mtk_lap_2d_test_02.dat");
00118
00119   if(!assertion) {
00120     std::cerr << "Error writing to file." << std::endl;
00121   }
00122
00123   mtk::Tools::EndUnitTestNo(2);
00124   mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129   std::cout << "Testing mtk::Lap2D class." << std::endl;
00130
00131   TestDefaultConstructorFactory();
00132   TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140   cout << "This code HAS to be compiled with support for C++11." << endl;
00141   cout << "Exiting..." << endl;
00142 }
00143 #endif
```

18.151 tests/mtk_lap_3d_test.cc File Reference

Test file for the mtk::Lap3D class.

`#include <iostream>`

Include dependency graph for mtk_lap_3d_test.cc:



Functions

- int main ()

18.151.1 Detailed Description

Author

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

Definition in file mtk_lap_3d_test.cc.

18.151.2 Function Documentation

18.151.2.1 int main ( )

Definition at line 145 of file mtk_lap_3d_test.cc.

18.152 mtk_lap_3d_test.cc

```
00001
00008 /*
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00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
00027
00028 4. Usage of the binary form on proprietary applications shall require explicit
00029 prior written permission from the the copyright holders, and due credit should
00030 be given to the copyright holders.
00031
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.
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00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
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00041
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
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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
```

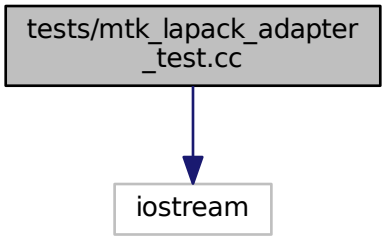
```
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::Lap3D ll;
00068
00069   mtk::Real aa = 0.0;
00070   mtk::Real bb = 1.0;
00071   mtk::Real cc = 0.0;
00072   mtk::Real dd = 1.0;
00073   mtk::Real ee = 0.0;
00074   mtk::Real ff = 1.0;
00075
00076   int nn = 5;
00077   int mm = 5;
00078   int oo = 5;
00079
00080   mtk::UniStgGrid3D llg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00081
00082   bool assertion = ll.ConstructLap3D(llg);
00083
00084   if (!assertion) {
00085     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00086   }
00087
00088   mtk::Tools::EndUnitTestNo(1);
00089   mtk::Tools::Assert(assertion);
00090 }
00091
00092 void TestReturnAsDenseMatrixWriteToFile() {
00093
00094   mtk::Tools::BeginUnitTestNo(2);
00095
00096   mtk::Lap3D ll;
00097
00098   mtk::Real aa = 0.0;
00099   mtk::Real bb = 1.0;
00100   mtk::Real cc = 0.0;
00101   mtk::Real dd = 1.0;
00102   mtk::Real ee = 0.0;
00103   mtk::Real ff = 1.0;
00104
00105   int nn = 5;
00106   int mm = 5;
00107   int oo = 5;
00108
00109   mtk::UniStgGrid3D llg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00110
00111   bool assertion = ll.ConstructLap3D(llg);
00112
00113   if (!assertion) {
00114     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00115   }
00116
00117   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00118
00119   assertion = assertion && (llm.num_rows() != 0);
00120
00121   std::cout << llm << std::endl;
00122
00123   assertion = assertion && llm.WriteToFile("mtk_lap_3d_test_02.dat");
00124
00125   if(!assertion) {
00126     std::cerr << "Error writing to file." << std::endl;
00127   }
00128
00129   mtk::Tools::EndUnitTestNo(2);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 int main () {
00134
00135   std::cout << "Testing mtk::Lap3D class." << std::endl;
00136
00137   TestDefaultConstructorFactory();
00138   TestReturnAsDenseMatrixWriteToFile();
00139 }
00140
00141 #else
```

```
00142 #include <iostream>
00143 using std::cout;
00144 using std::endl;
00145 int main () {
00146   cout << "This code HAS to be compiled with support for C++11." << endl;
00147   cout << "Exiting..." << endl;
00148 }
00149 #endif
```

18.153 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 ()

18.153.1 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.

18.153.2 Function Documentation

18.153.2.1 int main ( )

Definition at line 81 of file mtk_lapack_adapter_test.cc.

18.154 mtk_lapack_adapter_test.cc

```
00001
00010 /*
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00012 University. All rights reserved.
00013
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00015 are permitted provided that the following conditions are met:
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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00028 other materials provided with the distribution.
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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #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
```
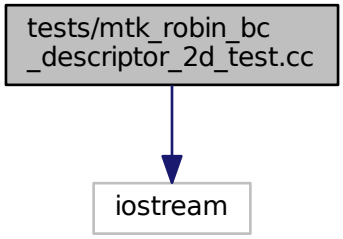

18.155 tests/mtk_robin_bc_descriptor_2d_test.cc File Reference

Test file for the mtk::RobinBCDescriptor2D class.

```
#include <iostream>
```

Include dependency graph for mtk_robin_bc_descriptor_2d_test.cc:



Functions

- int main ()

18.155.1 Detailed Description

Author

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

Definition in file mtk_robin_bc_descriptor_2d_test.cc.

18.155.2 Function Documentation

18.155.2.1 int main ( )

Definition at line 198 of file mtk_robin_bc_descriptor_2d_test.cc.

18.156 mtk_robin_bc_descriptor_2d_test.cc

```
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00010 University. All rights reserved.
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00013 are permitted provided that the following conditions are met:
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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.
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorGetters() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::RobinBCDescriptor2D bcd;
00068
00069   bool assertion{true};
00070
00071   assertion = assertion && bcd.highest_order_diff_west() == -1;
00072   assertion = assertion && bcd.highest_order_diff_east() == -1;
00073   assertion = assertion && bcd.highest_order_diff_south() == -1;
00074   assertion = assertion && bcd.highest_order_diff_north() == -1;
00075
00076   mtk::Tools::EndUnitTestNo(1);
00077   mtk::Tools::Assert(assertion);
00078 }
00079
00080 mtk::Real cc(const mtk::Real &xx, const mtk::Real &yy) {
00081
00082   return mtk::kOne;
00083 }
00084
00085 void TestPushBackImposeOnLaplacianMatrix() {
00086
00087   mtk::Tools::BeginUnitTestNo(2);
00088
00089   mtk::RobinBCDescriptor2D bcd;
00090
00091   bool assertion{true};
00092
00093   bcd.PushBackWestCoeff(cc);
00094   bcd.PushBackEastCoeff(cc);
00095   bcd.PushBackSouthCoeff(cc);
00096   bcd.PushBackNorthCoeff(cc);
00097
00098   assertion = assertion && bcd.highest_order_diff_west() == 0;
```

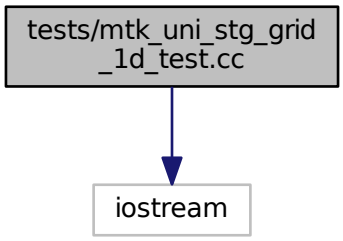
```
00099   assertion = assertion && bcd.highest_order_diff_east() == 0;
00100   assertion = assertion && bcd.highest_order_diff_south() == 0;
00101   assertion = assertion && bcd.highest_order_diff_north() == 0;
00102
00103   mtk::Real aa = 0.0;
00104   mtk::Real bb = 1.0;
00105   mtk::Real cc = 0.0;
00106   mtk::Real dd = 1.0;
00107
00108   int nn = 5;
00109   int mm = 5;
00110
00111   mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00112
00113   mtk::Lap2D ll;
00114
00115   assertion = ll.ConstructLap2D(llg);
00116
00117   if (!assertion) {
00118     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00119   }
00120
00121   mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00122
00123   assertion = assertion && (llm.num_rows() != 0);
00124
00125   bcd.ImposeOnLaplacianMatrix(ll, llg, llm);
00126
00127   assertion = assertion &&
00128     llm.WriteToFile("mtk_robin_bc_descriptor_2d_test_02.dat");
00129
00130   mtk::Tools::EndUnitTestNo(2);
00131   mtk::Tools::Assert(assertion);
00132 }
00133
00134 mtk::Real ScalarField(const mtk::Real &xx, const mtk::Real &yy) {
00135
00136   mtk::Real aux{-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy};
00137
00138   return xx*yy*exp(aux);
00139 }
00140
00141 mtk::Real HomogeneousDiricheletBC(const mtk::Real &xx,
00142                                   const mtk::Real &tt) {
00143
00144   return mtk::kZero;
00145 }
00146
00147 void TestImposeOnGrid() {
00148
00149   mtk::Tools::BeginUnitTestNo(3);
00150
00151   mtk::Real aa = 0.0;
00152   mtk::Real bb = 1.0;
00153   mtk::Real cc = 0.0;
00154   mtk::Real dd = 1.0;
00155
00156   int nn = 5;
00157   int mm = 5;
00158
00159   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00160
00161   gg.BindScalarField(ScalarField);
00162
00163   mtk::RobinBCDescriptor2D desc;
00164
00165   desc.set_west_condition(HomogeneousDiricheletBC);
00166   desc.set_east_condition(HomogeneousDiricheletBC);
00167   desc.set_south_condition(HomogeneousDiricheletBC);
00168   desc.set_north_condition(HomogeneousDiricheletBC);
00169
00170   desc.ImposeOnGrid(gg);
00171
00172   bool assertion{gg.WriteToFile("mtk_robin_bc_descriptor_2d_test_03.dat",
00173                                 "x",
00174                                 "y",
00175                                 "u(x,y)")};
00176
00177   if(!assertion) {
00178     std::cerr << "Error writing to file." << std::endl;
00179   }
```

```
00180
00181   mtk::Tools::EndUnitTestNo(3);
00182   mtk::Tools::Assert(assertion);
00183 }
00184
00185 int main () {
00186
00187   std::cout << "Testing mtk::RobinBCDescriptor2D class." << std::endl;
00188
00189   TestDefaultConstructorGetters();
00190   TestPushBackImposeOnLaplacianMatrix();
00191   TestImposeOnGrid();
00192 }
00193
00194 #else
00195 #include <iostream>
00196 using std::cout;
00197 using std::endl;
00198 int main () {
00199   cout << "This code HAS to be compiled with support for C++11." << endl;
00200   cout << "Exiting..." << endl;
00201 }
00202 #endif
```

18.157 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 ()

18.157.1 Detailed Description

Author

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

Definition in file mtk_uni_stg_grid_1d_test.cc.

18.157.2 Function Documentation

18.157.2.1 int main ( )

Definition at line 172 of file mtk_uni_stg_grid_1d_test.cc.

18.158 mtk_uni_stg_grid_1d_test.cc

```
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00008 /*
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00010 University. All rights reserved.
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00013 are permitted provided that the following conditions are met:
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
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00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00025 this list of conditions and the following disclaimer in the documentation and/or
00026 other materials provided with the distribution.
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00030 be given to the copyright holders.
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00033 may be used to endorse or promote products derived from this software without
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00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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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(const mtk::Real &xx) {
00072
00073   return 2.0*xx;
```

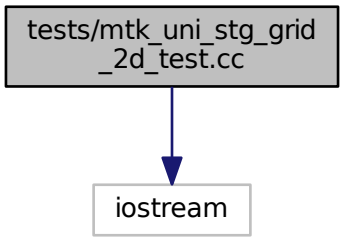
```
00074 }
00075
00076 void TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Real aa = 0.0;
00081   mtk::Real bb = 1.0;
00082
00083   int nn = 5;
00084
00085   mtk::UniStgGrid1D gg(aa, bb, nn);
00086
00087  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

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

18.159 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 ()

18.159.1 Detailed Description

Author

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

Definition in file mtk_uni_stg_grid_2d_test.cc.

18.159.2 Function Documentation

18.159.2.1 int main ( )

Definition at line 202 of file mtk_uni_stg_grid_2d_test.cc.

18.160 mtk_uni_stg_grid_2d_test.cc

```
00001
00008 /*
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00013 are permitted provided that the following conditions are met:
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
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00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructor() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::UniStgGrid2D gg;
00068
00069   mtk::Tools::EndUnitTestNo(1);
00070   mtk::Tools::Assert(gg.delta_x() == mtk::kZero && gg.
      delta_y() == mtk::kZero);
00071 }
00072
```

```
00073 void
00074 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator() {
00075
00076   mtk::Tools::BeginUnitTestNo(2);
00077
00078   mtk::Real aa = 0.0;
00079   mtk::Real bb = 1.0;
00080   mtk::Real cc = 0.0;
00081   mtk::Real dd = 1.0;
00082
00083   int nn = 5;
00084   int mm = 7;
00085
00086   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00087
00088   std::cout << gg << std::endl;
00089
00090   mtk::Tools::EndUnitTestNo(2);
00091   mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00092                      abs(gg.delta_y() - 0.142857) <
      mtk::kDefaultTolerance);
00093 }
00094
00095 void TestGetters() {
00096
00097   mtk::Tools::BeginUnitTestNo(3);
00098
00099   mtk::Real aa = 0.0;
00100   mtk::Real bb = 1.0;
00101   mtk::Real cc = 0.0;
00102   mtk::Real dd = 1.0;
00103
00104   int nn = 5;
00105   int mm = 7;
00106
00107   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00108
00109   bool assertion{true};
00110
00111   assertion = assertion && (gg.west_bndy() == aa);
00112   assertion = assertion && (gg.east_bndy() == bb);
00113   assertion = assertion && (gg.num_cells_x() == nn);
00114   assertion = assertion && (gg.south_bndy() == cc);
00115   assertion = assertion && (gg.north_bndy() == dd);
00116   assertion = assertion && (gg.num_cells_y() == mm);
00117
00118   mtk::Tools::EndUnitTestNo(3);
00119   mtk::Tools::Assert(assertion);
00120 }
00121
00122 mtk::Real ScalarField(const mtk::Real &xx, const mtk::Real &yy) {
00123
00124   mtk::Real aux{-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy};
00125
00126   return xx*yy*exp(aux);
00127 }
00128
00129 void TestBindScalarFieldWriteToFile() {
00130
00131   mtk::Tools::BeginUnitTestNo(4);
00132
00133   mtk::Real aa = 0.0;
00134   mtk::Real bb = 1.0;
00135   mtk::Real cc = 0.0;
00136   mtk::Real dd = 1.0;
00137
00138   int nn = 5;
00139   int mm = 5;
00140
00141   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00142
00143   gg.BindScalarField(ScalarField);
00144
00145   if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_04.dat", "x", "y", "u(x,y)")) {
00146     std::cerr << "Error writing to file." << std::endl;
00147   }
00148
00149   mtk::Tools::EndUnitTestNo(4);
00150 }
00151
00152 mtk::Real VectorFieldPComponent(const mtk::Real &xx, const
```

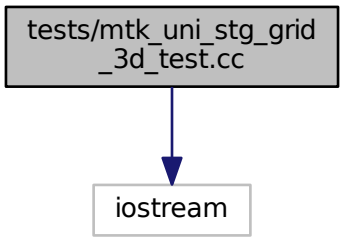
```
      mtk::Real &yy) {
00153
00154   return xx + 0.01;
00155 }
00156
00157 mtk::Real VectorFieldQComponent(const mtk::Real &xx, const
      mtk::Real &yy) {
00158
00159   return yy + 0.01;
00160 }
00161
00162 void TestBindVectorField() {
00163
00164   mtk::Tools::BeginUnitTestNo(5);
00165
00166   mtk::Real aa = 0.0;
00167   mtk::Real bb = 1.0;
00168   mtk::Real cc = 0.0;
00169   mtk::Real dd = 1.0;
00170
00171   int nn = 5;
00172   int mm = 5;
00173
00174   mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm,
      mtk::FieldNature::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
```

18.161 tests/mtk_uni_stg_grid_3d_test.cc File Reference

Test file for the mtk::UniStgGrid3D class.

```
#include <iostream>
```

Include dependency graph for mtk_uni_stg_grid_3d_test.cc:



Functions

- int main ()

18.161.1 Detailed Description

Author

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

Definition in file mtk_uni_stg_grid_3d_test.cc.

18.161.2 Function Documentation

18.161.2.1 int main ( )

Definition at line 184 of file mtk_uni_stg_grid_3d_test.cc.

18.162 mtk_uni_stg_grid_3d_test.cc

```
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00016 and a copy of the modified files should be reported once modifications are
00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00023
```

```
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructor() {
00064
00065   mtk::Tools::BeginUnitTestNo(1);
00066
00067   mtk::UniStgGrid3D gg;
00068
00069   mtk::Tools::EndUnitTestNo(1);
00070   mtk::Tools::Assert(gg.delta_x() == mtk::kZero &&
00071                      gg.delta_y() == mtk::kZero &&
00072                      gg.delta_z() == mtk::kZero);
00073 }
00074
00075 void
00076 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator() {
00077
00078   mtk::Tools::BeginUnitTestNo(2);
00079
00080   mtk::Real aa = 0.0;
00081   mtk::Real bb = 1.0;
00082   mtk::Real cc = 0.0;
00083   mtk::Real dd = 1.0;
00084   mtk::Real ee = 0.0;
00085   mtk::Real ff = 1.0;
00086
00087   int nn = 5;
00088   int mm = 7;
00089   int oo = 7;
00090
00091   mtk::UniStgGrid3D gg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00092
00093   std::cout << gg << std::endl;
00094
00095   mtk::Tools::EndUnitTestNo(2);
00096   mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00097                      abs(gg.delta_y() - 0.142857) <
      mtk::kDefaultTolerance);
00098 }
00099
00100 void TestGetters() {
00101
00102   mtk::Tools::BeginUnitTestNo(3);
00103
```

```
00104   mtk::Real aa = 0.0;
00105   mtk::Real bb = 1.0;
00106   mtk::Real cc = 0.0;
00107   mtk::Real dd = 1.0;
00108   mtk::Real ee = 0.0;
00109   mtk::Real ff = 1.0;
00110
00111   int nn = 5;
00112   int mm = 7;
00113   int oo = 6;
00114
00115   mtk::UniStgGrid3D gg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00116
00117   bool assertion{true};
00118
00119   assertion = assertion && (gg.west_bndy() == aa);
00120   assertion = assertion && (gg.east_bndy() == bb);
00121   assertion = assertion && (gg.num_cells_x() == nn);
00122   assertion = assertion && (gg.south_bndy() == cc);
00123   assertion = assertion && (gg.north_bndy() == dd);
00124   assertion = assertion && (gg.num_cells_y() == mm);
00125   assertion = assertion && (gg.bottom_bndy() == ee);
00126   assertion = assertion && (gg.top_bndy() == ff);
00127   assertion = assertion && (gg.num_cells_z() == oo);
00128
00129   mtk::Tools::EndUnitTestNo(3);
00130   mtk::Tools::Assert(assertion);
00131 }
00132
00133 mtk::Real ScalarField(const mtk::Real &xx,
00134                       const mtk::Real &yy,
00135                       const mtk::Real &zz) {
00136
00137   return xx + yy + zz;
00138 }
00139
00140 void TestBindScalarFieldWriteToFile() {
00141
00142   mtk::Tools::BeginUnitTestNo(4);
00143
00144   mtk::Real aa = 0.0;
00145   mtk::Real bb = 1.0;
00146   mtk::Real cc = 0.0;
00147   mtk::Real dd = 1.0;
00148   mtk::Real ee = 0.0;
00149   mtk::Real ff = 1.0;
00150
00151   int nn = 50;
00152   int mm = 50;
00153   int oo = 50;
00154
00155   mtk::UniStgGrid3D gg(aa, bb, nn, cc, dd, mm, ee, ff, oo);
00156
00157   gg.BindScalarField(ScalarField);
00158
00159   if(!gg.WriteToFile("mtk_uni_stg_grid_3d_test_04.dat",
00160                      "x",
00161                      "y",
00162                      "z",
00163                      "u(x,y,z)")) {
00164     std::cerr << "Error writing to file." << std::endl;
00165   }
00166
00167   mtk::Tools::EndUnitTestNo(4);
00168 }
00169
00170 int main () {
00171
00172   std::cout << "Testing mtk::UniStgGrid3D class." << std::endl;
00173
00174   TestDefaultConstructor();
00175   TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOStreamOperator();
00176   TestGetters();
00177   TestBindScalarFieldWriteToFile();
00178 }
00179
00180 #else
00181 #include <iostream>
00182 using std::cout;
00183 using std::endl;
00184 int main () {
```

```
00185   cout << "This code HAS to be compiled with support for C++11." << endl;
00186   cout << "Exiting..." << endl;
00187 }
00188 #endif
```

Index