

MTK: Mimetic Methods Toolkit

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Chapter 1

Introduction

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

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

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

1.1 MTK Concerns

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

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

In order of dependence these are:

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

1.2 MTK Flavors

The MTK collection of wrappers is:

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

Others are being designed and developed.

1.3 Contact, Support and Credits

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

Developers are members of:

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

Currently the developers are:

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5. Angel Boada.
6. Johnny Corbino.
7. Raul Vargas–Navarro.

1.4 Acknowledgements and Contributions

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

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

Chapter 2

Programming Tools

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

1. Editor: Kate - KDE Advanced Text Editor. Version 3.13.3. Using KDE Development Platform 4.13.3 (C) 2000-2005 The Kate Authors.
2. Compiler: gcc version 4.4.5 (Ubuntu/Linaro 4.4.4-14ubuntu5). Copyright (C) 2013 Free Software Foundation, Inc.
3. Debugger: GNU gdb (Ubuntu 7.7.1-0ubuntu5~14.04.2) 7.7.1. Copyright (C) 2014 Free Software Foundation, Inc.
4. Memory Profiler: valgrind-3.10.0.SVN.

Chapter 3

Licensing and Modifications

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

1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu and a copy of the modified files should be reported once modifications are completed, unless these modifications are made through the project's GitHub page: <http://www.csrc.sdsu.edu/mtk>. Documentation related to said modifications should be developed and included in any deliverable.
2. Redistributions of source code must be done through direct downloads from the project's GitHub page: <http://www.csrc.sdsu.edu/mtk>
3. Redistributions in binary form must reproduce the above copyright notice, this list of conditions and the following disclaimer in the documentation and/or other materials provided with the distribution.
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Chapter 4

Read Me File and Installation Instructions

README File for the Mimetic Methods Toolkit (MTK)

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

1. Description

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

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

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

2. Dependencies

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

`$(HOME)/Libraries/`

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

For Linux:

1. LAPACK - Available from: <http://www.netlib.org/lapack/>
 1. BLAS - Available from: <http://www.netlib.org/blas/>
2. GLPK - Available from: <https://www.gnu.org/software/glpk/>
3. (Optional) ATLAS - Available from: <http://math-atlas.sourceforge.net/>
 1. LAPACK - Available from: <http://www.netlib.org/lapack/>
 1. BLAS - Available from: <http://www.netlib.org/blas/>
4. (Optional) Valgrind - Available from: <http://valgrind.org/>
5. (Optional) Doxygen - Available from <http://www.stack.nl/~dimitri/doxygen/>

For OS X:

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

3. Installation

PART 1. CONFIGURATION OF THE MAKEFILE.

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

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

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

- testall: runs all the tests.

- gendoc: generates the documentation for the library.

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

PART 2. BUILD THE LIBRARY.

```
$ make
```

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

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

Examples and tests will also be built.

4. Frequently Asked Questions

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

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

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

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

Q: Do I need to generate the documentation myself?

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

5. Contact, Support, and Credits

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

Developers are members of:

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

Currently the developers are:

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

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

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

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

Thanks and happy coding!

Chapter 5

Tests and Test Architectures

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

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

1. Linux 3.2.0-23-generic-pae #36-Ubuntu SMP i386 GNU/Linux.
Intel(R) Pentium(R) M CPU 1.73 GHz 2048 KB of cache and stepping of 8.
gcc version 4.6.3 (Ubuntu/Linaro 4.6.3-1ubuntu5).
2. Linux 3.13.0-67-generic #110-Ubuntu SMP x86_64 GNU/Linux.
Intel(R) Core(TM) i7-4700MQ CPU 2.40 GHz 6144 KB of cache and stepping of 3.
gcc version 4.8.4 (Ubuntu 4.4.4-2ubuntu1~14.04).
3. Linux 3.16.7-29-desktop #1 SMP PREEMPT (6be6a97) x86_64 GNU/Linux
Intel(R) Core(TM) i7-4600U CPU 2.10 GHz 4096 KB of cache and a stepping of 1.
gcc (SUSE Linux) 4.8.3 20140627 [gcc-4_8-branch revision 212064].

Further architectures will be tested!

Chapter 6

Examples

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

Chapter 7

User Manual, References and Theory

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

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

However, a .PDF copy of this manual can be found [here](#).

Chapter 8

Todo List

Member `mtk::DenseMatrix::data () const`

Test the const-correctness of the returned pointer.

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

Implement Kronecker product using the BLAS.

Member `mtk::DenseMatrix::OrderColMajor ()`

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

Member `mtk::DenseMatrix::OrderRowMajor ()`

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

Member `mtk::DenseMatrix::Transpose ()`

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

Class `mtk::GLPKAdapter`

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

Member `mtk::Matrix::IncreaseNumNull ()`

Review the definition of sparse matrices properties.

Member `mtk::Matrix::IncreaseNumZero ()`

Review the definition of sparse matrices properties.

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

Check if this is the best way of stalling execution.

Member `mtk::Tools::test_number_`

Check usage of static methods and private members.

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

Review const-correctness of the pointer we return.

Member `mtk::UniStgGrid1D::discrete_field_u ()`

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

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

Review const-correctness of the pointer we return.

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

Review const-correctness of the pointer we return.

File [mtk_div_1d.cc](#)

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

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

File [mtk_glpk_adapter_test.cc](#)

Test the [mtk::GLPKAdapter](#) class.

File [mtk_grad_1d.cc](#)

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

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

File [mtk_lapack_adapter.cc](#)

Write documentation using LaTeX.

File [mtk_lapack_adapter_test.cc](#)

Test the [mtk::LAPACKAdapter](#) class.

File [mtk_quad_1d.h](#)

Implement this class.

File [mtk_roots.h](#)

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

Test selective precision mechanisms.

File [mtk_uni_stg_grid_1d.h](#)

Create overloaded binding routines that read data from files.

File [mtk_uni_stg_grid_2d.h](#)

Create overloaded binding routines that read data from files.

Chapter 9

Bug List

Member `mtk::Matrix::set_num_null` (int in)

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

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

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

Chapter 10

Module Index

10.1 Modules

Here is a list of all modules:

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Chapter 11

Namespace Index

11.1 Namespace List

Here is a list of all namespaces with brief descriptions:

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

Chapter 12

Class Index

12.1 Class List

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

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mtk::BCDescriptor2D	53
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mtk::DenseMatrix	Defines a common dense matrix, using a 1D array	64
mtk::Div1D	Implements a 1D mimetic divergence operator	81
mtk::Div2D	93
mtk::GLPKAdapter	Adapter class for the GLPK API	97
mtk::Grad1D	Implements a 1D mimetic gradient operator	100
mtk::Grad2D	112
mtk::Interp1D	Implements a 1D interpolation operator	116
mtk::Interp2D	120
mtk::Lap1D	Implements a 1D mimetic Laplacian operator	123
mtk::Lap2D	128
mtk::LAPACKAdapter	Adapter class for the LAPACK API	132
mtk::Matrix	Definition of the representation of a matrix in the MTK	138
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Chapter 13

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13.1 File List

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include/mtk_lap_2d.h	Includes the implementation of the class Lap2D	223
include/mtk_lapack_adapter.h	Adapter class for the LAPACK API	226
include/mtk_matrix.h	Definition of the representation of a matrix in the MTK	228
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include/mtk_tools.h	Tool manager class	236
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include/mtk_uni_stg_grid_2d.h	Definition of an 2D uniform staggered grid	241
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Chapter 14

Module Documentation

14.1 Roots.

Fundamental execution parameters and defined types.

Typedefs

- typedef float `mtk::Real`

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

Variables

- const float `mtk::kZero` {0.0f}
MTK's zero defined according to selective compilation.
- const float `mtk::kOne` {1.0f}
MTK's one defined according to selective compilation.
- const float `mtk::kDefaultTolerance` {1e-7f}
Considered tolerance for comparisons in numerical methods.
- const int `mtk::kDefaultOrderAccuracy` {2}
Default order of accuracy for mimetic operators.
- const float `mtk::kDefaultMimeticThreshold` {1e-6f}
Default tolerance for higher-order mimetic operators.
- const int `mtk::kCriticalOrderAccuracyDiv` {8}
At this order (and higher) we must use the CBSA to construct.
- const int `mtk::kCriticalOrderAccuracyGrad` {10}
At this order (and higher) we must use the CBSA to construct.

14.1.1 Detailed Description

Fundamental execution parameters and defined types.

14.1.2 Typedef Documentation

14.1.2.1 `mtk::Real`

Definition at line 83 of file [mtk_roots.h](#).

14.1.3 Variable Documentation

14.1.3.1 `mtk::kCriticalOrderAccuracyDiv {8}`

Definition at line 157 of file [mtk_roots.h](#).

14.1.3.2 `mtk::kCriticalOrderAccuracyGrad {10}`

Definition at line 166 of file [mtk_roots.h](#).

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

Warning

Declared as double if `MTK_PRECISION_DOUBLE` is defined.

Definition at line 147 of file [mtk_roots.h](#).

14.1.3.4 `mtk::kDefaultOrderAccuracy {2}`

Warning

Declared as double if `MTK_PRECISION_DOUBLE` is defined.

Definition at line 133 of file [mtk_roots.h](#).

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

Definition at line 121 of file [mtk_roots.h](#).

14.1.3.6 `mtk::kOne {1.0f}`

Warning

Declared as double if `MTK_PRECISION_DOUBLE` is defined.

Definition at line 108 of file [mtk_roots.h](#).

14.1.3.7 `mtk::kZero {0.0f}`

Warning

Declared as double if `MTK_PRECISION_DOUBLE` is defined.

Definition at line 107 of file [mtk_roots.h](#).

14.2 Enumerations.

Enumerations.

Enumerations

- enum `mtk::MatrixStorage` { `mtk::DENSE`, `mtk::BANDED`, `mtk::CRS` }
Considered matrix storage schemes to implement sparse matrices.
- enum `mtk::MatrixOrdering` { `mtk::ROW_MAJOR`, `mtk::COL_MAJOR` }
Considered matrix ordering (for Fortran purposes).
- enum `mtk::FieldNature` { `mtk::SCALAR`, `mtk::VECTOR` }
Nature of the field discretized in a given grid.
- enum `mtk::DirInterp` { `mtk::SCALAR_TO_VECTOR`, `mtk::VECTOR_TO_SCALAR` }
Interpolation operator.

14.2.1 Detailed Description

Enumerations.

14.2.2 Enumeration Type Documentation

14.2.2.1 enum `mtk::DirInterp`

Used to tag different directions of interpolation supported.

Enumerator

SCALAR_TO_VECTOR Interpolations places scalar on vectors' location.

VECTOR_TO_SCALAR Interpolations places vectors on scalars' location.

Definition at line 127 of file `mtk_enums.h`.

14.2.2.2 enum `mtk::FieldNature`

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

See also

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

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

Enumerator

SCALAR Scalar-valued field.

VECTOR Vector-valued field.

Definition at line 113 of file `mtk_enums.h`.

14.2.2.3 enum mtk::MatrixOrdering

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

See also

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

Enumerator

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

COL_MAJOR Column-major ordering (Fortran).

Definition at line 95 of file [mtk_enums.h](#).

14.2.2.4 enum mtk::MatrixStorage

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

Enumerator

DENSE Dense matrices, implemented as a 1D array: [DenseMatrix](#).

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

CRS Compressed-Rows Storage: Must be implemented.

Definition at line 77 of file [mtk_enums.h](#).

14.3 Execution tools.

Tools to ensure execution correctness.

Classes

- class `mtk::Tools`

Tool manager class.

14.3.1 Detailed Description

Tools to ensure execution correctness.

14.4 Data structures.

Fundamental data structures.

Classes

- class [mtk::DenseMatrix](#)
Defines a common dense matrix, using a 1D array.
- class [mtk::Matrix](#)
Definition of the representation of a matrix in the MTK.

14.4.1 Detailed Description

Fundamental data structures.

14.5 Numerical methods.

Adapter classes and auxiliary numerical methods.

Classes

- class [mtk::BLASAdapter](#)
Adapter class for the BLAS API.
- class [mtk::GLPKAdapter](#)
Adapter class for the GLPK API.
- class [mtk::LAPACKAdapter](#)
Adapter class for the LAPACK API.

14.5.1 Detailed Description

Adapter classes and auxiliary numerical methods.

14.6 Grids.

Uniform rectangular staggered grids.

Classes

- class [mtk::UniStgGrid1D](#)
Uniform 1D Staggered Grid.
- class [mtk::UniStgGrid2D](#)
Uniform 2D Staggered Grid.

14.6.1 Detailed Description

Uniform rectangular staggered grids.

14.7 Mimetic operators.

Mimetic operators.

Classes

- class [mtk::BCDescriptor1D](#)
Enforces boundary conditions in either the operator or the grid.
- class [mtk::Div1D](#)
Implements a 1D mimetic divergence operator.
- class [mtk::Grad1D](#)
Implements a 1D mimetic gradient operator.
- class [mtk::Interp1D](#)
Implements a 1D interpolation operator.
- class [mtk::Lap1D](#)
Implements a 1D mimetic Laplacian operator.
- class [mtk::Quad1D](#)
Implements a 1D mimetic quadrature.

Typedefs

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

14.7.1 Detailed Description

Mimetic operators.

14.7.2 Typedef Documentation

14.7.2.1 [mtk::CoefficientFunction2D](#)

Definition at line 91 of file [mtk_bc_descriptor_2d.h](#).

Chapter 15

Namespace Documentation

15.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

Classes

- class [BCDescriptor1D](#)
Enforces boundary conditions in either the operator or the grid.
- class [BCDescriptor2D](#)
- class [BLASAdapter](#)
Adapter class for the BLAS API.
- class [DenseMatrix](#)
Defines a common dense matrix, using a 1D array.
- class [Div1D](#)
Implements a 1D mimetic divergence operator.
- class [Div2D](#)
- class [GLPKAdapter](#)
Adapter class for the GLPK API.
- class [Grad1D](#)
Implements a 1D mimetic gradient operator.
- class [Grad2D](#)
- class [Interp1D](#)
Implements a 1D interpolation operator.
- class [Interp2D](#)
- class [Lap1D](#)
Implements a 1D mimetic Laplacian operator.
- class [Lap2D](#)
- class [LAPACKAdapter](#)
Adapter class for the LAPACK API.
- class [Matrix](#)
Definition of the representation of a matrix in the MTK.
- class [Quad1D](#)
Implements a 1D mimetic quadrature.

- class [Tools](#)
Tool manager class.
- class [UniStgGrid1D](#)
Uniform 1D Staggered Grid.
- class [UniStgGrid2D](#)
Uniform 2D Staggered Grid.

Typedefs

- typedef [Real](#)(* [CoefficientFunction2D](#))([Real](#), [Real](#))
A function of a BC coefficient evaluated on a 2D domain.
- typedef float [Real](#)
Users can simply change this to build a double- or single-precision MTK.

Enumerations

- enum [MatrixStorage](#) { [DENSE](#), [BANDED](#), [CRS](#) }
Considered matrix storage schemes to implement sparse matrices.
- enum [MatrixOrdering](#) { [ROW_MAJOR](#), [COL_MAJOR](#) }
Considered matrix ordering (for Fortran purposes).
- enum [FieldNature](#) { [SCALAR](#), [VECTOR](#) }
Nature of the field discretized in a given grid.
- enum [DirInterp](#) { [SCALAR_TO_VECTOR](#), [VECTOR_TO_SCALAR](#) }
Interpolation operator.

Functions

- float [snrm2_](#) (int *n, float *x, int *incx)
- void [saxpy_](#) (int *n, float *sa, float *sx, int *incx, float *sy, int *incy)
- void [sgemv_](#) (char *trans, int *m, int *n, float *alpha, float *a, int *lda, float *x, int *incx, float *beta, float *y, int *incy)
- void [sgemm_](#) (char *transa, char *transb, int *m, int *n, int *k, double *alpha, double *a, int *lda, double *b, aamm int *ldb, double *beta, double *c, int *ldc)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::DenseMatrix](#) &in)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::Div1D](#) &in)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::Grad1D](#) &in)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::Interp1D](#) &in)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::Lap1D](#) &in)
- void [sgesv_](#) (int *n, int *nrhs, [Real](#) *a, int *lda, int *ipiv, [Real](#) *b, int *ldb, int *info)
- void [sgels_](#) (char *trans, int *m, int *n, int *nrhs, [Real](#) *a, int *lda, [Real](#) *b, int *ldb, [Real](#) *work, int *lwork, int *info)
Single-precision GEneral matrix Least Squares solver.
- void [sgeqrf_](#) (int *m, int *n, [Real](#) *a, int *lda, [Real](#) *tau, [Real](#) *work, int *lwork, int *info)
Single-precision GEneral matrix QR Factorization.
- void [sormqr_](#) (char *side, char *trans, int *m, int *n, int *k, [Real](#) *a, int *lda, [Real](#) *tau, [Real](#) *c, int *ldc, [Real](#) *work, int *lwork, int *info)
Single-precision Orthogonal [Matrix](#) from QR factorization.
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::UniStgGrid1D](#) &in)
- std::ostream & [operator<<](#) (std::ostream &stream, [mtk::UniStgGrid2D](#) &in)

Variables

- const float [kZero](#) {0.0f}
MTK's zero defined according to selective compilation.
- const float [kOne](#) {1.0f}
MTK's one defined according to selective compilation.
- const float [kDefaultTolerance](#) {1e-7f}
Considered tolerance for comparisons in numerical methods.
- const int [kDefaultOrderAccuracy](#) {2}
Default order of accuracy for mimetic operators.
- const float [kDefaultMimeticThreshold](#) {1e-6f}
Default tolerance for higher-order mimetic operators.
- const int [kCriticalOrderAccuracyDiv](#) {8}
At this order (and higher) we must use the CBSA to construct.
- const int [kCriticalOrderAccuracyGrad](#) {10}
At this order (and higher) we must use the CBSA to construct.

15.1.1 Function Documentation

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

1. Print approximating coefficients for the interior.

Definition at line 66 of file [mtk_interp_1d.cc](#).

15.1.1.2 `std::ostream& mtk::operator<< (std::ostream & stream, mtk::UniStgGrid2D & in)`

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

Definition at line 67 of file [mtk_uni_stg_grid_2d.cc](#).

15.1.1.3 `std::ostream& mtk::operator<< (std::ostream & stream, mtk::UniStgGrid1D & in)`

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

Definition at line 68 of file [mtk_uni_stg_grid_1d.cc](#).

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

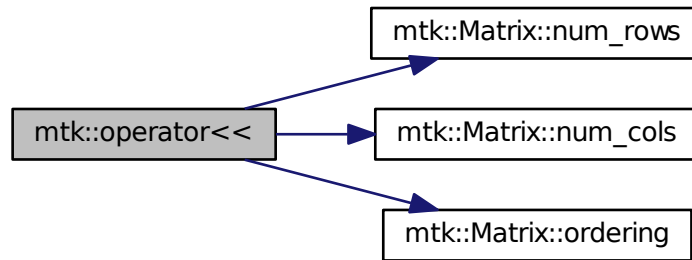
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 73 of file [mtk_lap_1d.cc](#).

15.1.1.5 `std::ostream& mtk::operator<< (std::ostream & stream, mtk::DenseMatrix & in)`

Definition at line 77 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



15.1.1.6 `std::ostream& mtk::operator<< (std::ostream & stream, mtk::Grad1D & in)`

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

Definition at line 79 of file [mtk_grad_1d.cc](#).

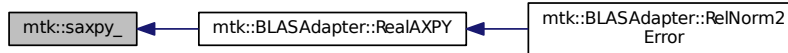
15.1.1.7 `std::ostream& mtk::operator<< (std::ostream & stream, mtk::Div1D & in)`

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

Definition at line 79 of file [mtk_div_1d.cc](#).

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

Here is the caller graph for this function:



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

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

The following options are provided:

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

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

2. If TRANS = 'N' and $m < n$: find the minimum norm solution of an underdetermined system $A * X = B$.

3. If TRANS = 'T' and $m \geq n$: find the minimum norm solution of an undetermined system $A^{**T} * X = B$.

4. If TRANS = 'T' and $m < n$: find the least squares solution of an overdetermined system, i.e., solve the least squares problem

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

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

See also

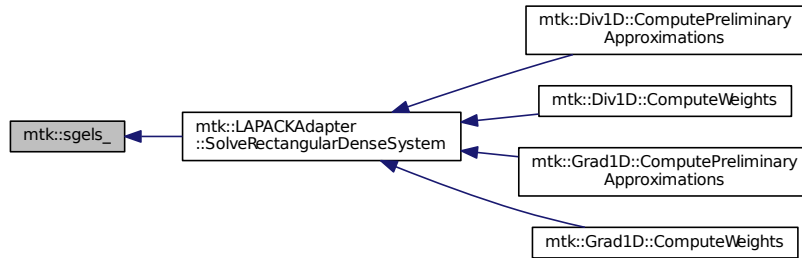
<http://www.math.utah.edu/software/lapack/lapack-s/sgels.html>

Parameters

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

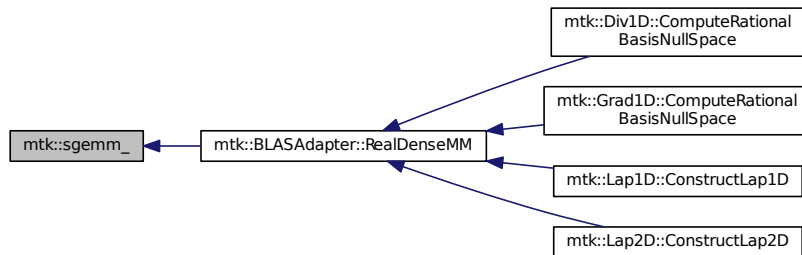
in, out	<i>b</i>	On entry, matrix b of right-hand side vectors.
in	<i>ldb</i>	The leading dimension of b. $ldb \geq \max(1, m, n)$.
in, out	<i>work</i>	On exit, if <i>info</i> = 0, <i>work</i> (1) is optimal <i>lwork</i> .
in, out	<i>lwork</i>	The dimension of the array <i>work</i> .
in, out	<i>info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

Here is the caller graph for this function:



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

Here is the caller graph for this function:



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

Here is the caller graph for this function:



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

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

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

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

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

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

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

See also

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

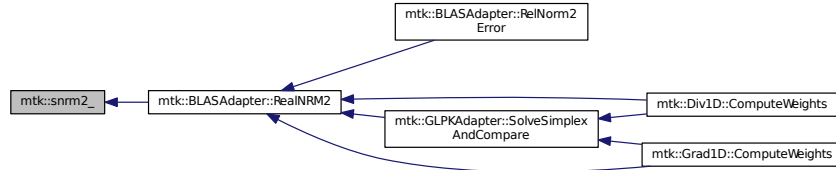
Parameters

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

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

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

Here is the caller graph for this function:



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

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

SIDE = 'L' SIDE = 'R'

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

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

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

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

See also

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

Parameters

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

<code>in, out</code>	<i>info</i>	info = 0: successful exit.
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Chapter 16

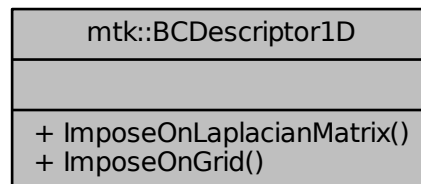
Class Documentation

16.1 mtk::BCDescriptor1D Class Reference

Enforces boundary conditions in either the operator or the grid.

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

Collaboration diagram for mtk::BCDescriptor1D:



Static Public Member Functions

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

Enforces the condition on the Laplacian represented as matrix.

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

Enforces the condition on the grid.

16.1.1 Detailed Description

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

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

16.1.2 Member Function Documentation

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

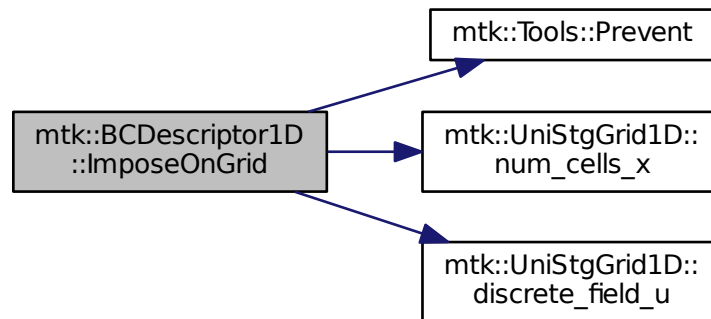
Parameters

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

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

Definition at line 89 of file [mtk_bc_descriptor_1d.cc](#).

Here is the call graph for this function:



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

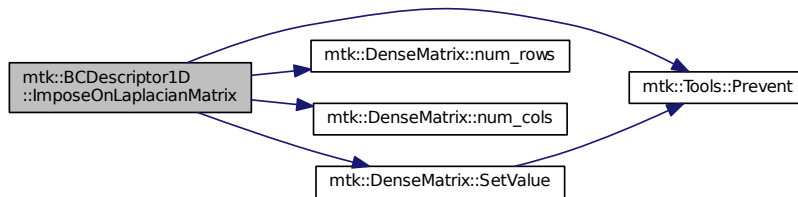
Parameters

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

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

Definition at line 61 of file [mtk_bc_descriptor_1d.cc](#).

Here is the call graph for this function:



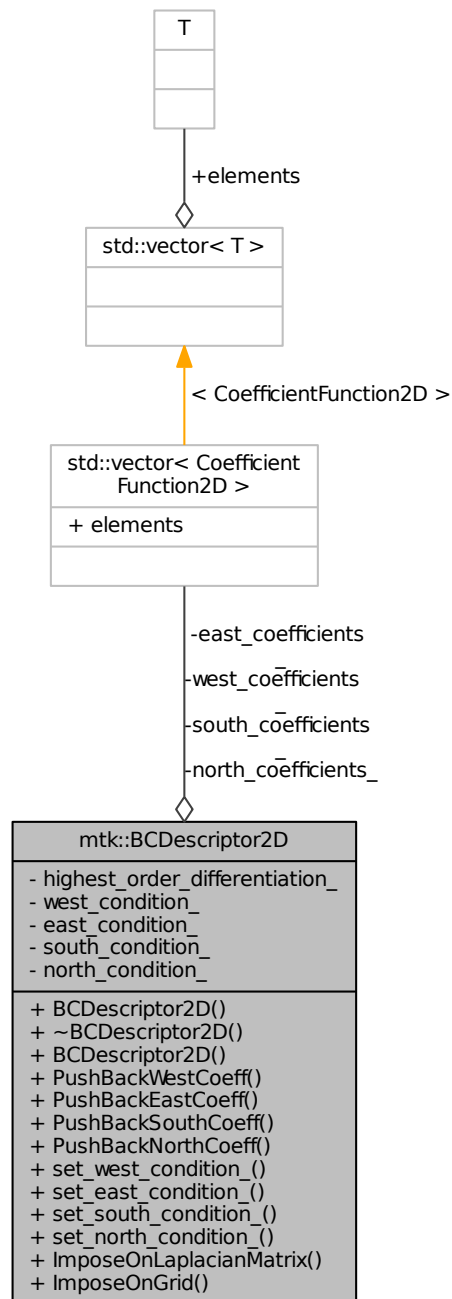
The documentation for this class was generated from the following files:

- [include/mtk_bc_descriptor_1d.h](#)
- [src/mtk_bc_descriptor_1d.cc](#)

16.2 mtk::BCDescriptor2D Class Reference

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

Collaboration diagram for `mtk::BCDescriptor2D`:



Public Member Functions

- [BCDescriptor2D](#) ()

- *Default constructor.*
- [~BCDescriptor2D](#) ()
- *Destructor.*
- [BCDescriptor2D](#) (const [BCDescriptor2D](#) &desc)
- *Copy constructor.*
- void [PushBackWestCoeff](#) ([CoefficientFunction2D](#) cw)
- *Push back coefficient function at west of lowest order diff. available.*
- void [PushBackEastCoeff](#) ([CoefficientFunction2D](#) ce)
- *Push back coefficient function at east of lowest order diff. available.*
- void [PushBackSouthCoeff](#) ([CoefficientFunction2D](#) cs)
- *Push back coefficient function south of lowest order diff. available.*
- void [PushBackNorthCoeff](#) ([CoefficientFunction2D](#) cn)
- *Push back coefficient function north of lowest order diff. available.*
- void [set_west_condition_](#) (mtk::Real(*[west_condition_](#))([Real](#) xx, [Real](#) yy))
- *Set boundary condition at west.*
- void [set_east_condition_](#) (mtk::Real(*[east_condition_](#))([Real](#) xx, [Real](#) yy))
- *Set boundary condition at east.*
- void [set_south_condition_](#) (mtk::Real(*[south_condition_](#))([Real](#) xx, [Real](#) yy))
- *Set boundary condition at south.*
- void [set_north_condition_](#) (mtk::Real(*[north_condition_](#))([Real](#) xx, [Real](#) yy))
- *Set boundary condition at north.*
- void [ImposeOnLaplacianMatrix](#) (const [UniStgGrid2D](#) &grid, [DenseMatrix](#) &matrix) const
- *Imposes the condition on the operator represented as matrix.*
- void [ImposeOnGrid](#) ([UniStgGrid2D](#) &grid) const
- *Imposes the condition on the grid.*

Private Attributes

- int [highest_order_differentiation_](#)
- *Highest order of differentiation.*
- std::vector
- [CoefficientFunction2D](#) > [west_coefficients_](#)
- *Coeffs. west.*
- std::vector
- [CoefficientFunction2D](#) > [east_coefficients_](#)
- *Coeffs. east.*
- std::vector
- [CoefficientFunction2D](#) > [south_coefficients_](#)
- *Coeffs. south.*
- std::vector
- [CoefficientFunction2D](#) > [north_coefficients_](#)
- *Coeffs. south.*
- mtk::Real(* [west_condition_](#))([Real](#) xx, [Real](#) yy)
- *Condition for west.*
- mtk::Real(* [east_condition_](#))([Real](#) xx, [Real](#) yy)
- *Condition for east.*
- mtk::Real(* [south_condition_](#))([Real](#) xx, [Real](#) yy)
- *Condition for south.*
- mtk::Real(* [north_condition_](#))([Real](#) xx, [Real](#) yy)
- *Condition for north.*

16.2.1 Detailed Description

Definition at line 93 of file [mtk_bc_descriptor_2d.h](#).

16.2.2 Constructor & Destructor Documentation

16.2.2.1 `mtk::BCDescriptor2D::BCDescriptor2D ()`

16.2.2.2 `mtk::BCDescriptor2D::~~BCDescriptor2D ()`

16.2.2.3 `mtk::BCDescriptor2D::BCDescriptor2D (const BCDescriptor2D & desc)`

Parameters

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

16.2.3 Member Function Documentation

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

Parameters

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

16.2.3.2 `void mtk::BCDescriptor2D::ImposeOnLaplacianMatrix (const UniStgGrid2D & grid, DenseMatrix & matrix) const`

Parameters

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

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

Parameters

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

16.2.3.4 `void mtk::BCDescriptor2D::PushBackNorthCoeff (CoefficientFunction2D cn)`

Parameters

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

16.2.3.5 `void mtk::BCDescriptor2D::PushBackSouthCoeff (CoefficientFunction2D cs)`

Parameters

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

16.2.3.6 void mtk::BCDescriptor2D::PushBackWestCoeff (CoefficientFunction2D cw)

Parameters

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

16.2.3.7 void mtk::BCDescriptor2D::set_east_condition_ (mtk::Real(*) (Real xx, Real yy) east_condition_)

Parameters

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

16.2.3.8 void mtk::BCDescriptor2D::set_north_condition_ (mtk::Real(*) (Real xx, Real yy) north_condition_)

Parameters

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

16.2.3.9 void mtk::BCDescriptor2D::set_south_condition_ (mtk::Real(*) (Real xx, Real yy) south_condition_)

Parameters

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

16.2.3.10 void mtk::BCDescriptor2D::set_west_condition_ (mtk::Real(*) (Real xx, Real yy) west_condition_)

Parameters

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

16.2.4 Member Data Documentation

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

Definition at line 184 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 189 of file [mtk_bc_descriptor_2d.h](#).

16.2.4.3 `int mtk::BCDescriptor2D::highest_order_differentiation_ [private]`

Definition at line 181 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 186 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 191 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 185 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 190 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 183 of file [mtk_bc_descriptor_2d.h](#).

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

Definition at line 188 of file [mtk_bc_descriptor_2d.h](#).

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

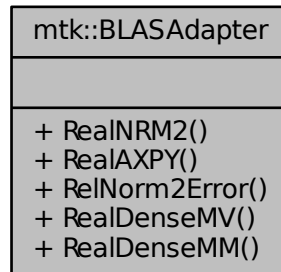
- [include/mtk_bc_descriptor_2d.h](#)

16.3 mtk::BLASAdapter Class Reference

Adapter class for the BLAS API.

```
#include <mtk_blas_adapter.h>
```


Collaboration diagram for mtk::BLASAdapter:



Static Public Member Functions

- static [Real](#) [RealINRM2](#) ([Real](#) *in, int &in_length)
Compute the $\|x\|_2$ of given array x .
- static void [RealAXPY](#) ([Real](#) alpha, [Real](#) *xx, [Real](#) *yy, int &in_length)
Real-Arithmetic Scalar-Vector plus a Vector.
- static [Real](#) [RelNorm2Error](#) ([Real](#) *computed, [Real](#) *known, int length)
Computes the relative norm-2 of the error.
- static void [RealDenseMV](#) ([Real](#) &alpha, [DenseMatrix](#) &aa, [Real](#) *xx, [Real](#) &beta, [Real](#) *yy)
Real-Arithmetic General (Dense matrices) Matrix-Vector Multiplier.
- static [DenseMatrix](#) [RealDenseMM](#) ([DenseMatrix](#) &aa, [DenseMatrix](#) &bb)
Real-Arithmetic General (Dense matrices) Matrix-Matrix multiplier.

16.3.1 Detailed Description

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

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

See also

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

Definition at line 96 of file [mtk_blas_adapter.h](#).

16.3.2 Member Function Documentation

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

Performs

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

Parameters

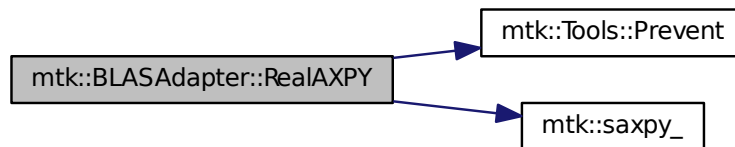
in	<i>alpha</i>	Scalar of the first array.
in	<i>xx</i>	First array.
in	<i>yy</i>	Second array.
in	<i>in_length</i>	Lengths of the given arrays.

Returns

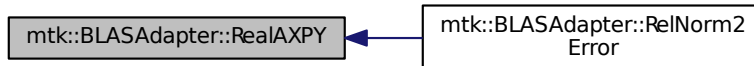
Norm-2 of the given array.

Definition at line 339 of file [mtk_blas_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs:

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

Parameters

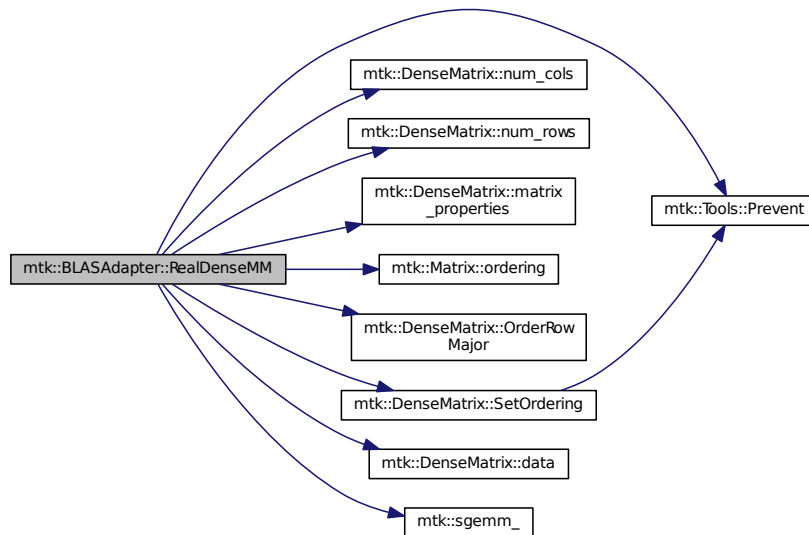
in	<i>aa</i>	First matrix.
in	<i>bb</i>	Second matrix.

See also

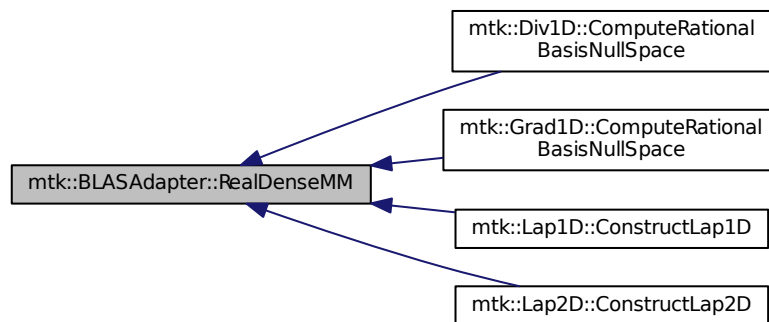
<http://ejspeiro.github.io/Netlib-and-CPP/>

Definition at line 409 of file [mtk_blas_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs

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

Parameters

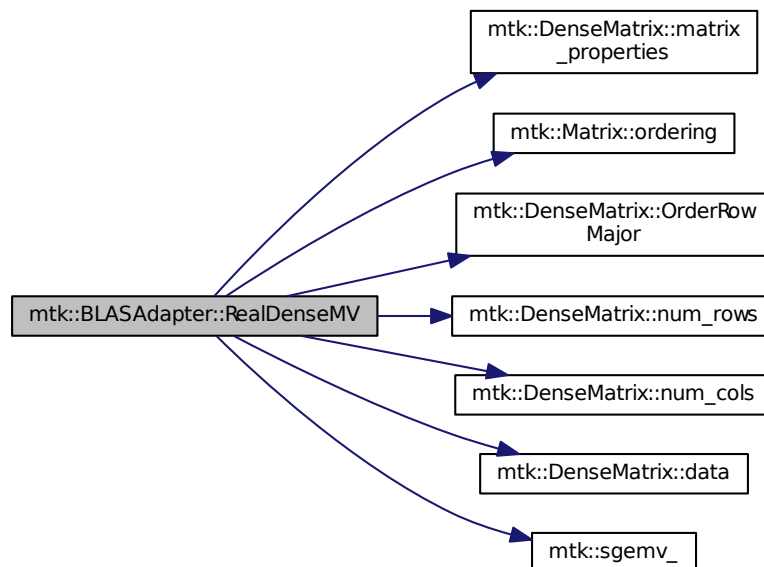
in	<i>alpha</i>	First scalar.
in	<i>aa</i>	Given matrix.
in	<i>xx</i>	First vector.
in	<i>beta</i>	Second scalar.
in, out	<i>yy</i>	Second vector (output).

See also

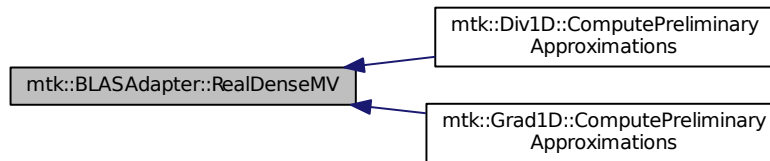
<http://ejspeiro.github.io/Netlib-and-CPP/>

Definition at line 378 of file [mtk_blas_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Parameters

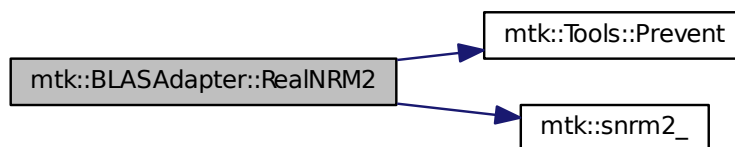
<code>in</code>	<code>in</code>	Input array.
<code>in</code>	<code>in_length</code>	Length of the array.

Returns

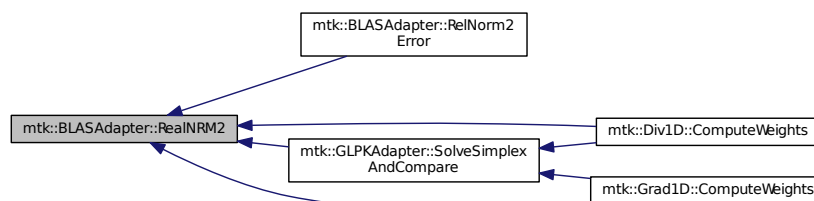
Norm-2 of the given array.

Definition at line 324 of file [mtk_blas_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

We compute

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

Parameters

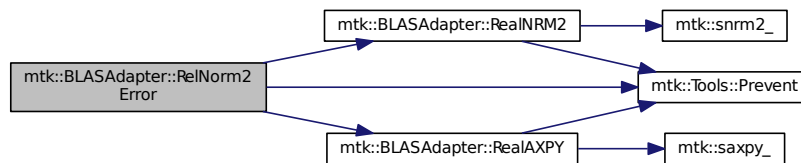
in	<i>known</i>	Array containing the computed solution.
in	<i>computed</i>	Array containing the known solution (ref. solution).

Returns

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

Definition at line 358 of file [mtk_blas_adapter.cc](#).

Here is the call graph for this function:



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

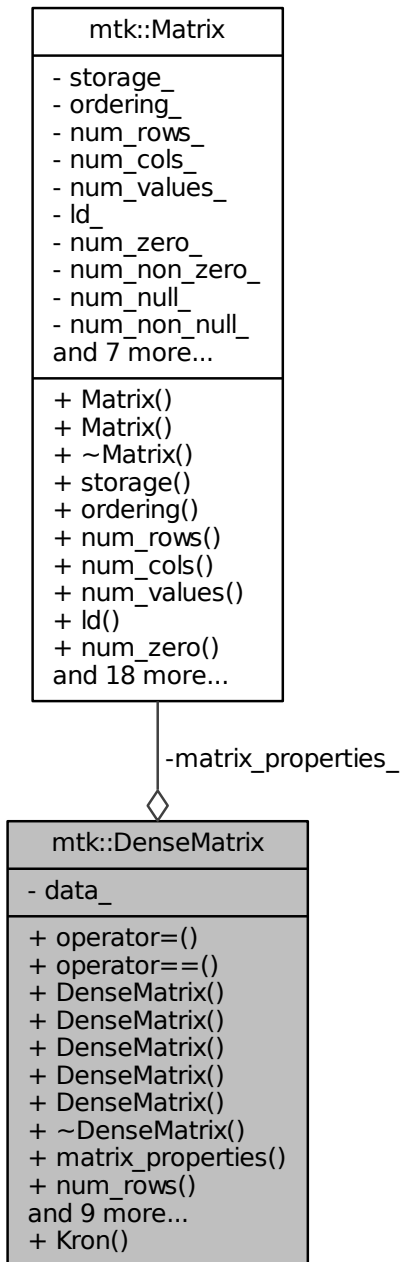
- [include/mtk_blas_adapter.h](#)
- [src/mtk_blas_adapter.cc](#)

16.4 mtk::DenseMatrix Class Reference

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

```
#include <mtk_dense_matrix.h>
```

Collaboration diagram for mtk::DenseMatrix:



Public Member Functions

- [DenseMatrix](#) & [operator=](#) (const [DenseMatrix](#) &in)

Overloaded assignment operator.

- `bool operator== (const DenseMatrix &in)`

Am I equal to the in matrix?

- `DenseMatrix ()`

Default constructor.

- `DenseMatrix (const DenseMatrix &in)`

Copy constructor.

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

Construct a dense matrix based on the given dimensions.

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

Construct a zero-rows-padded identity matrix.

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

Construct a dense Vandermonde matrix.

- `~DenseMatrix ()`

Destructor.

- `Matrix matrix_properties () const`

Provides access to the matrix data.

- `int num_rows () const`

Gets the number of rows.

- `int num_cols () const`

Gets the number of columns.

- `Real * data () const`

Provides access to the matrix value array.

- `void SetOrdering (mtk::MatrixOrdering oo)`

Sets the ordering of the matrix.

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

Gets a value on the given coordinates.

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

Sets a value on the given coordinates.

- `void Transpose ()`

Transpose this matrix.

- `void OrderRowMajor ()`

Make the matrix row-wise ordered.

- `void OrderColMajor ()`

Make the matrix column-wise ordered.

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

Writes matrix to a file compatible with Gnuplot 4.6.

Static Public Member Functions

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

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

Private Attributes

- [Matrix](#) `matrix_properties_`
Data related to the matrix nature.
- [Real](#) * `data_`
Array holding the data in contiguous position in memory.

Friends

- `std::ostream & operator<< (std::ostream &stream, DenseMatrix &in)`
Prints the matrix as a block of numbers (standard way).

16.4.1 Detailed Description

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

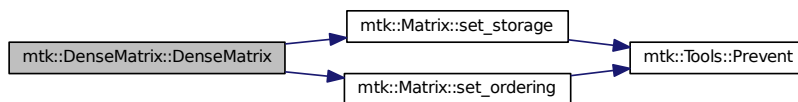
Definition at line 92 of file [mtk_dense_matrix.h](#).

16.4.2 Constructor & Destructor Documentation

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

Definition at line 162 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



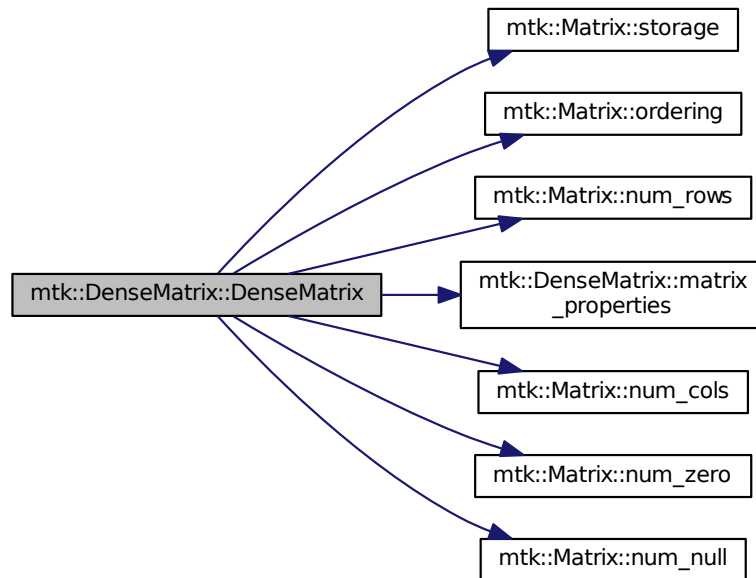
16.4.2.2 `mtk::DenseMatrix::DenseMatrix (const DenseMatrix &in)`

Parameters

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

Definition at line 168 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



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

Parameters

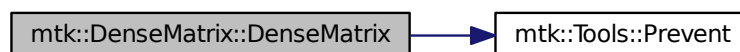
in	<i>num_rows</i>	Number of rows of the required matrix.
in	<i>num_cols</i>	Number of rows of the required matrix.

Exceptions

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

Definition at line 201 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



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

Used in the construction of the mimetic operators.

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

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

Parameters

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

Exceptions

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

Definition at line 223 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



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

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

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

This constructor generates a Vandermonde matrix, as defined above.

Obs**. It is important to understand that the generator vectors to be used are nothing but a very particular instance of a grid. These are little chunks, little samples, if you will, of a grid which is rectangular and uniform. So the selected samples, on the [mtk::Div1D](#) and [mtk::Grad1D](#), basically represent the entire space, the entire grid. This is why neither the CRS nor the CBS algorithms may work for irregular geometries, such as curvilinear grids.

Parameters

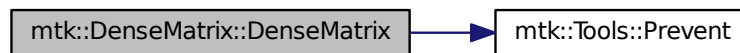
in	<i>gen</i>	Given generator vector.
in	<i>gen_length</i>	Length generator vector.
in	<i>pro_length</i>	Length the progression.
in	<i>transpose</i>	Should the transpose be created instead?

Exceptions

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

Definition at line [264](#) of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



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

Definition at line [312](#) of file [mtk_dense_matrix.cc](#).

16.4.3 Member Function Documentation

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

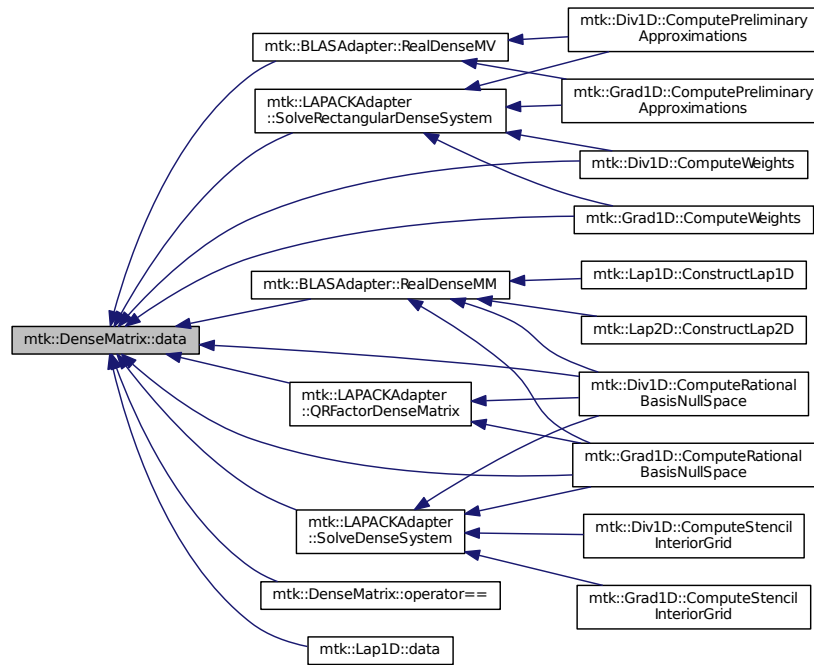
Returns

Pointer to an array of [mtk::Real](#).

Todo Test the const-correctness of the returned pointer.

Definition at line 343 of file [mtk_dense_matrix.cc](#).

Here is the caller graph for this function:



16.4.3.2 mtk::Real mtk::DenseMatrix::GetValue (const int & row_coord, const int & col_coord) const

Parameters

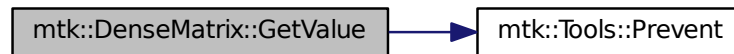
in	<i>row_coord</i>	Row coordinate.
in	<i>col_coord</i>	Column coordinate.

Returns

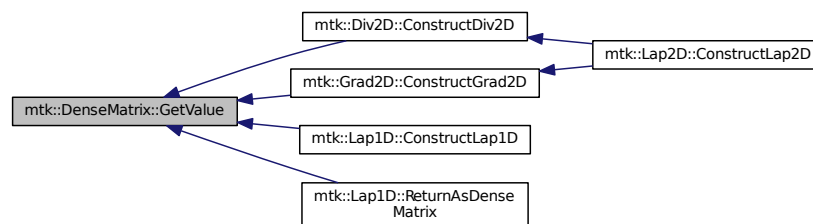
The required value at the specified coordinates.

Definition at line 348 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Parameters

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

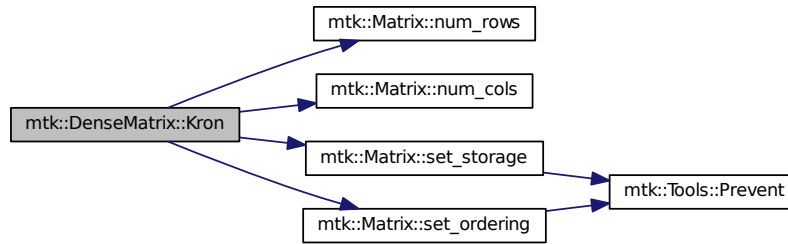
Exceptions

<code>std::bad_alloc</code>

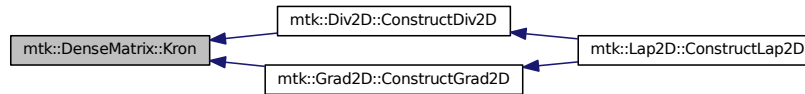
Todo Implement Kronecker product using the BLAS.

Definition at line 490 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



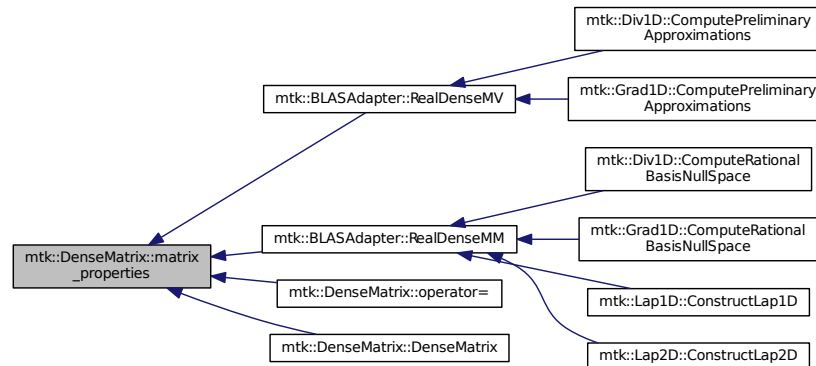
16.4.3.4 mtk::Matrix mtk::DenseMatrix::matrix_properties () const

Returns

Pointer to a [Matrix](#).

Definition at line 318 of file [mtk_dense_matrix.cc](#).

Here is the caller graph for this function:



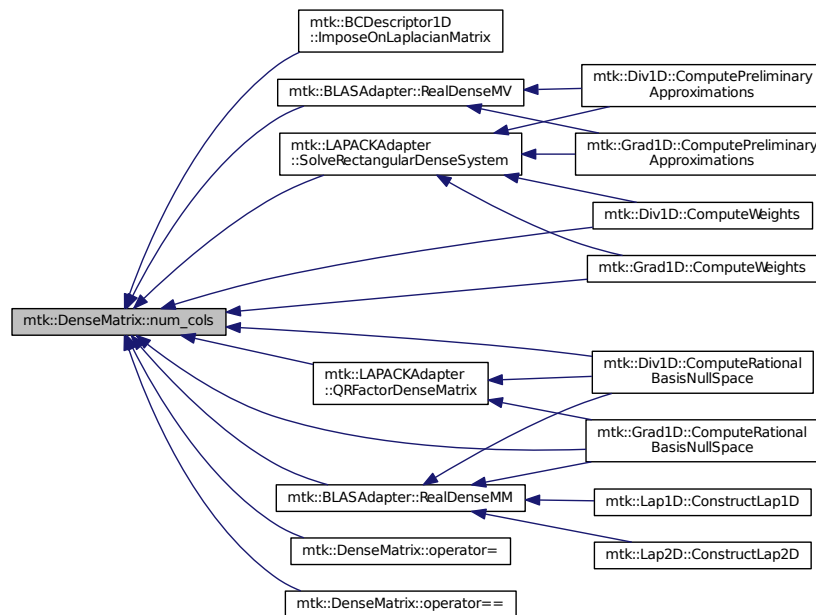
16.4.3.5 int mtk::DenseMatrix::num_cols () const

Returns

Number of columns of the matrix.

Definition at line 338 of file [mtk_dense_matrix.cc](#).

Here is the caller graph for this function:



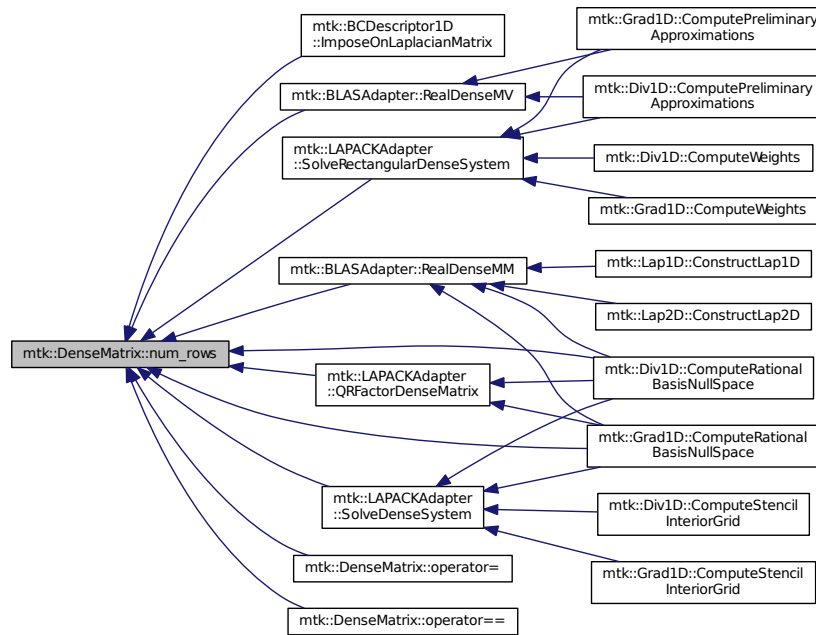
16.4.3.6 int mtk::DenseMatrix::num_rows () const

Returns

Number of rows of the matrix.

Definition at line 333 of file [mtk_dense_matrix.cc](#).

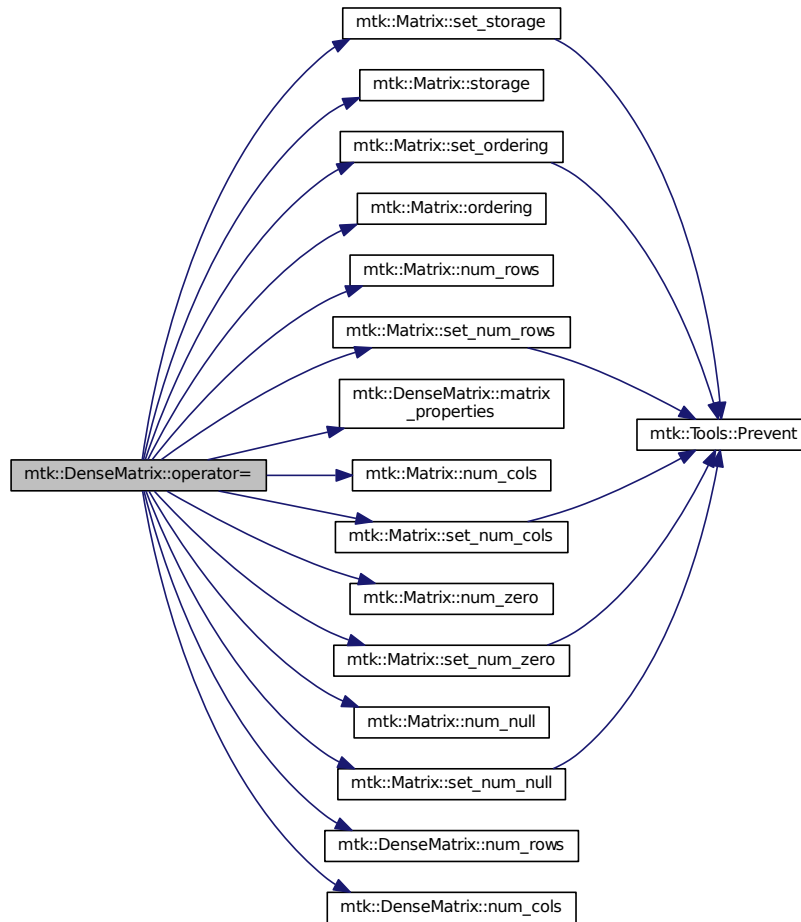
Here is the caller graph for this function:



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

Definition at line 100 of file [mtk_dense_matrix.cc](#).

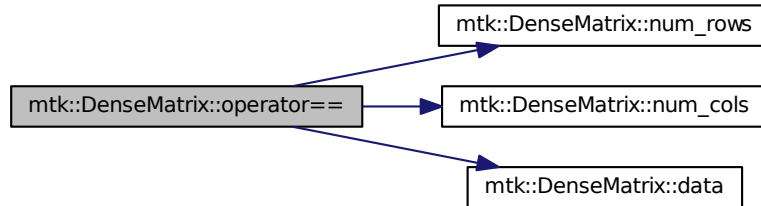
Here is the call graph for this function:



16.4.3.8 `bool mtk::DenseMatrix::operator==(const DenseMatrix & in)`

Definition at line 141 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:

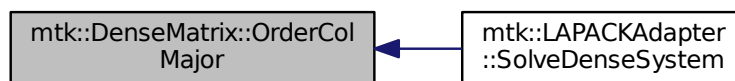


16.4.3.9 `void mtk::DenseMatrix::OrderColMajor ()`

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

Definition at line 451 of file [mtk_dense_matrix.cc](#).

Here is the caller graph for this function:

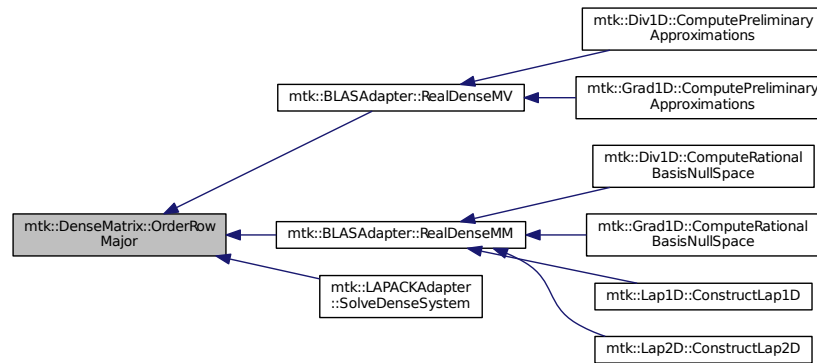


16.4.3.10 `void mtk::DenseMatrix::OrderRowMajor ()`

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

Definition at line 410 of file [mtk_dense_matrix.cc](#).

Here is the caller graph for this function:



16.4.3.11 `void mtk::DenseMatrix::SetOrdering (mtk::MatrixOrdering oo)`

Parameters

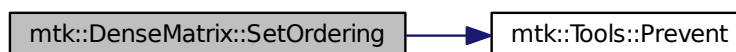
in	oo	Ordering.
----	----	-----------

Returns

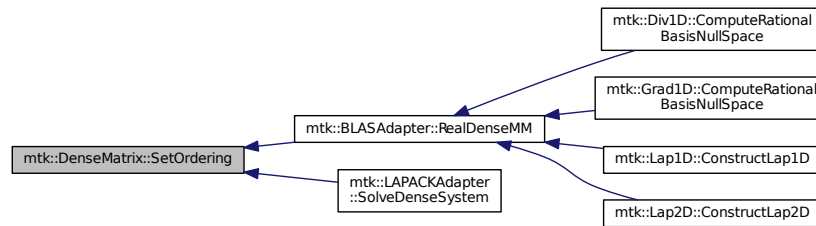
The required value at the specified coordinates.

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

Here is the call graph for this function:



Here is the caller graph for this function:



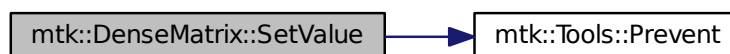
16.4.3.12 `void mtk::DenseMatrix::SetValue (const int & row_coord, const int & col_coord, const Real & val)`

Parameters

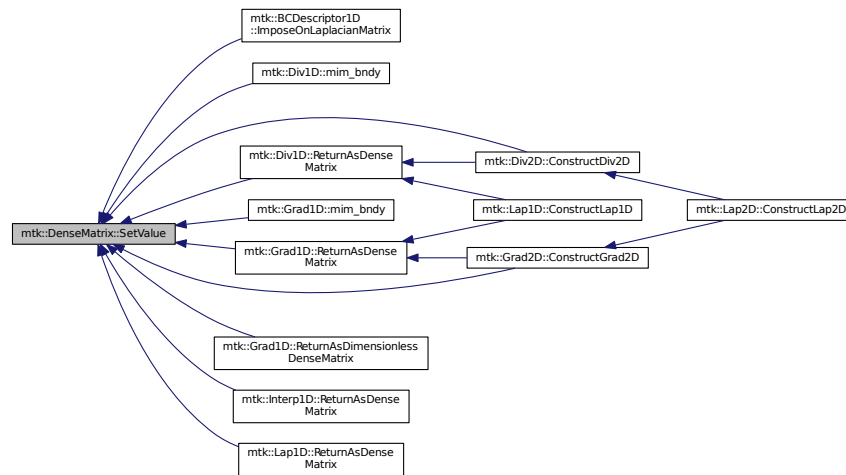
in	<i>row_coord</i>	Row coordinate.
in	<i>col_coord</i>	Column coordinate.
in	<i>val</i>	Row Actual value to be inserted.

Definition at line 360 of file [mtk_dense_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:

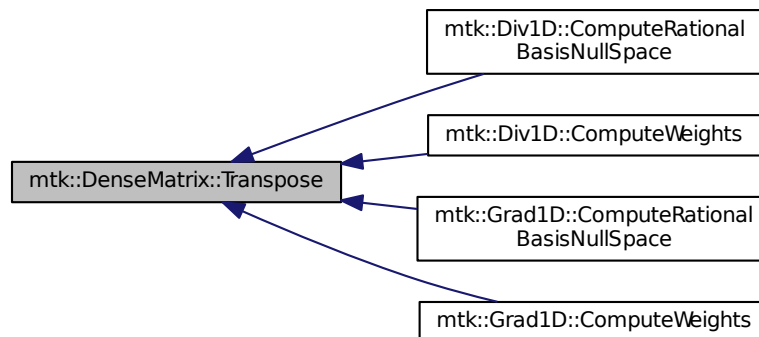


16.4.3.13 `void mtk::DenseMatrix::Transpose ()`

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

Definition at line 373 of file `mtk_dense_matrix.cc`.

Here is the caller graph for this function:



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

Parameters

<code>in</code>	<code>filename</code>	Name of the output file.
-----------------	-----------------------	--------------------------

Returns

Success of the file writing process.

See also

<http://www.gnuplot.info/>

Definition at line 531 of file [mtk_dense_matrix.cc](#).

16.4.4 Friends And Related Function Documentation

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

Definition at line 77 of file [mtk_dense_matrix.cc](#).

16.4.5 Member Data Documentation

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

Definition at line 286 of file [mtk_dense_matrix.h](#).

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

Definition at line 284 of file [mtk_dense_matrix.h](#).

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

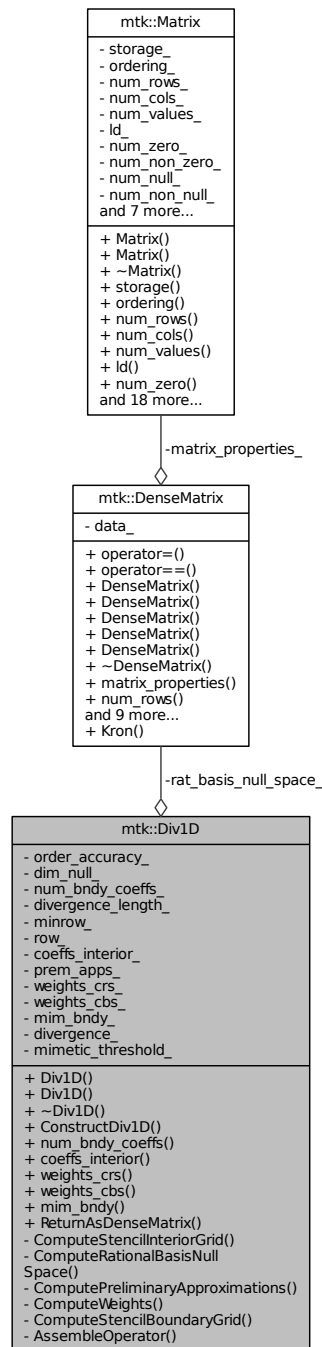
- [include/mtk_dense_matrix.h](#)
- [src/mtk_dense_matrix.cc](#)

16.5 mtk::Div1D Class Reference

Implements a 1D mimetic divergence operator.

```
#include <mtk_div_1d.h>
```

Collaboration diagram for mtk::Div1D:



Public Member Functions

- [Div1D \(\)](#)

- Default constructor.*
- [Div1D](#) (const [Div1D](#) &div)
- Copy constructor.*
- [~Div1D](#) ()
- Destructor.*
- bool [ConstructDiv1D](#) (int order_accuracy=[kDefaultOrderAccuracy](#), [Real](#) mimetic_threshold=[kDefaultMimeticThreshold](#))
- Factory method implementing the CBS Algorithm to build operator.*
- int [num_bndy_coefs](#) () const
- Returns how many coefficients are approximating at the boundary.*
- [Real](#) * [coefs_interior](#) () const
- Returns coefficients for the interior of the grid.*
- [Real](#) * [weights_crs](#) (void) const
- Return collection of weights as computed by the CRSA.*
- [Real](#) * [weights_cbs](#) (void) const
- Return collection of weights as computed by the CBSA.*
- [DenseMatrix](#) [mim_bndy](#) () const
- Return collection of mimetic approximations at the boundary.*
- [DenseMatrix](#) [ReturnAsDenseMatrix](#) (const [UniStgGrid1D](#) &grid) const
- Return the operator as a dense matrix.*

Private Member Functions

- bool [ComputeStencilInteriorGrid](#) (void)
- Stage 1 of the CBS Algorithm.*
- bool [ComputeRationalBasisNullSpace](#) (void)
- Stage 2.1 of the CBS Algorithm.*
- bool [ComputePreliminaryApproximations](#) (void)
- Stage 2.2 of the CBS Algorithm.*
- bool [ComputeWeights](#) (void)
- Stage 2.3 of the CBS Algorithm.*
- bool [ComputeStencilBoundaryGrid](#) (void)
- Stage 2.4 of the CBS Algorithm.*
- bool [AssembleOperator](#) (void)
- Stage 3 of the CBS Algorithm.*

Private Attributes

- int [order_accuracy_](#)
- Order of numerical accuracy of the operator.*
- int [dim_null_](#)
- Dim. null-space for boundary approximations.*
- int [num_bndy_coefs_](#)
- Req. coefs. per bndy pt. uni. order accuracy.*
- int [divergence_length_](#)
- Length of the output array.*
- int [minrow_](#)

- *Row from the optimizer with the minimum rel. nor.*
- `int row_`
Row currently processed by the optimizer.
- `DenseMatrix rat_basis_null_space_`
Rational b. null-space w. bndy.
- `Real * coeffs_interior_`
Interior stencil.
- `Real * prem_apps_`
2D array of boundary preliminary approximations.
- `Real * weights_crs_`
Array containing weights from CRSA.
- `Real * weights_cbs_`
Array containing weights from CBSA.
- `Real * mim_bndy_`
Array containing mimetic boundary approximations.
- `Real * divergence_`
Output array containing the operator and weights.
- `Real mimetic_threshold_`
< Mimetic threshold.

Friends

- `std::ostream & operator<< (std::ostream &stream, Div1D &in)`
Output stream operator for printing.

16.5.1 Detailed Description

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

Definition at line 81 of file `mtk_div_1d.h`.

16.5.2 Constructor & Destructor Documentation

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

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

16.5.2.2 `mtk::Div1D::Div1D (const Div1D &div)`

Parameters

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

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

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

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

16.5.3 Member Function Documentation

16.5.3.1 `bool mtk::Div1D::AssembleOperator (void) [private]`

Construct the output array with the operator and its weights.

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

Definition at line [1334](#) of file [mtk_div_1d.cc](#).

16.5.3.2 `mtk::Real * mtk::Div1D::coeffs_interior () const`

Returns

Coefficients for the interior of the grid.

Definition at line [320](#) of file [mtk_div_1d.cc](#).

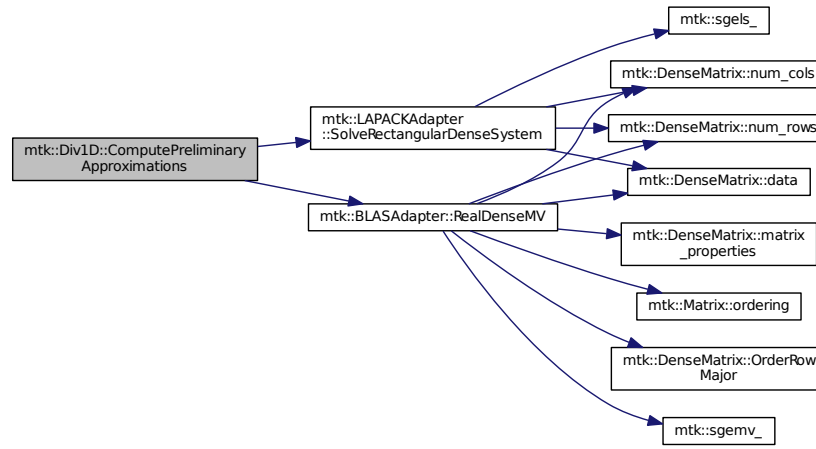
16.5.3.3 `bool mtk::Div1D::ComputePreliminaryApproximations (void) [private]`

Compute the set of preliminary approximations on the boundary neighborhood.

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

Definition at line [689](#) of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



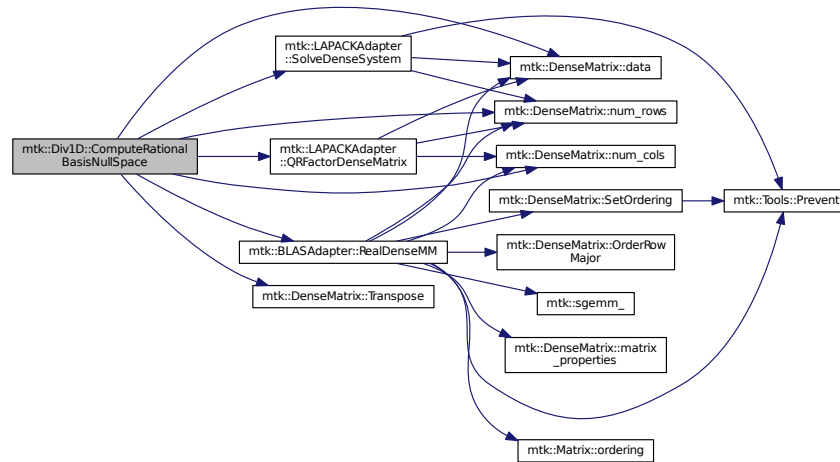
16.5.3.4 `bool mtk::Div1D::ComputeRationalBasisNullSpace (void) [private]`

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

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

Definition at line 513 of file `mtk_div_1d.cc`.

Here is the call graph for this function:



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

Compute mimetic stencil approximating at boundary.

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

Definition at line 1235 of file [mtk_div_1d.cc](#).

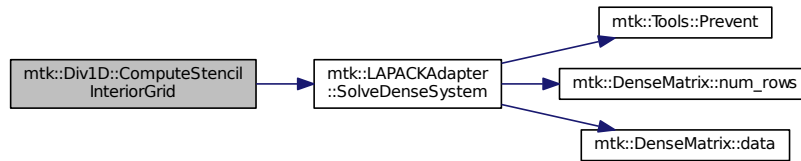
16.5.3.6 bool mtk::Div1D::ComputeStencilInteriorGrid (void) [private]

Compute the stencil approximating the interior of the staggered grid.

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

Definition at line 414 of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



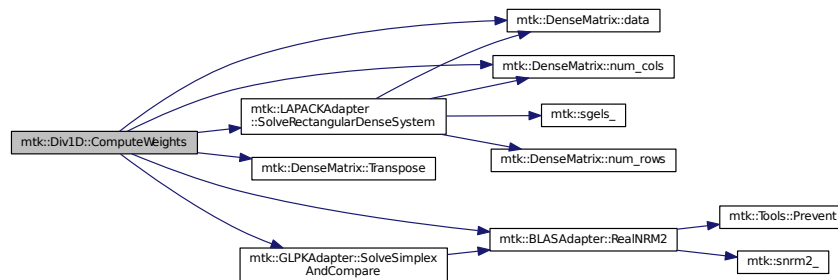
16.5.3.7 bool mtk::Div1D::ComputeWeights (void) [private]

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

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

Definition at line 909 of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



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

Returns

Success of the construction.

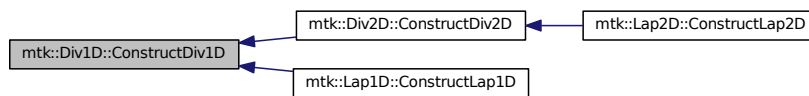
1. Compute stencil for the interior cells.
2. Compute a rational basis for the null-space for the first matrix.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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

Definition at line 176 of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



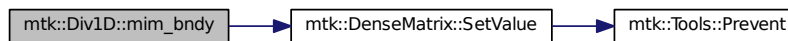
16.5.3.9 `mtk::DenseMatrix mtk::Div1D::mim_bndy () const`

Returns

Collection of mimetic approximations at the boundary.

Definition at line 336 of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



16.5.3.10 `int mtk::Div1D::num_bndy_coeffs () const`

Returns

How many coefficients are approximating at the boundary.

Definition at line 315 of file [mtk_div_1d.cc](#).

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

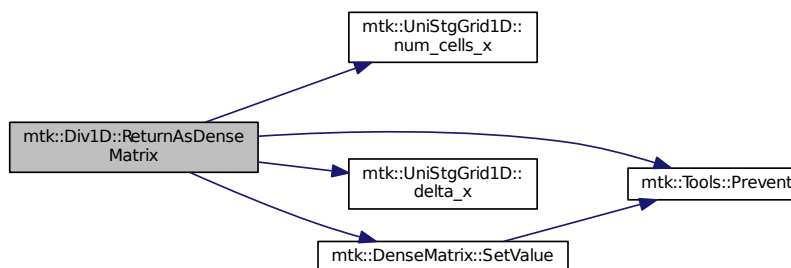
Returns

The operator as a dense matrix.

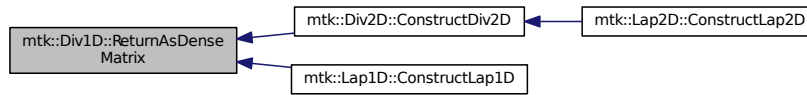
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 351 of file [mtk_div_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



16.5.3.12 `mtk::Real * mtk::Div1D::weights_cbs (void) const`

Returns

Collection of weights as computed by the CBSA.

Definition at line 330 of file [mtk_div_1d.cc](#).

16.5.3.13 `mtk::Real * mtk::Div1D::weights_crs (void) const`

Returns

Collection of weights as computed by the CRSA.

Definition at line 325 of file [mtk_div_1d.cc](#).

16.5.4 Friends And Related Function Documentation

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

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

Definition at line 79 of file [mtk_div_1d.cc](#).

16.5.5 Member Data Documentation

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

Definition at line 202 of file [mtk_div_1d.h](#).

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

Definition at line 194 of file [mtk_div_1d.h](#).

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

Definition at line 207 of file [mtk_div_1d.h](#).

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

Definition at line 196 of file [mtk_div_1d.h](#).

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

Definition at line 206 of file [mtk_div_1d.h](#).

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

Definition at line 209 of file [mtk_div_1d.h](#).

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

Definition at line 197 of file [mtk_div_1d.h](#).

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

Definition at line 195 of file [mtk_div_1d.h](#).

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

Definition at line 193 of file [mtk_div_1d.h](#).

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

Definition at line 203 of file [mtk_div_1d.h](#).

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

Definition at line 200 of file [mtk_div_1d.h](#).

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

Definition at line 198 of file [mtk_div_1d.h](#).

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

Definition at line 205 of file [mtk_div_1d.h](#).

16.5.5.14 `Real* mtk::Div1D::weights_crs_` [private]

Definition at line 204 of file [mtk_div_1d.h](#).

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

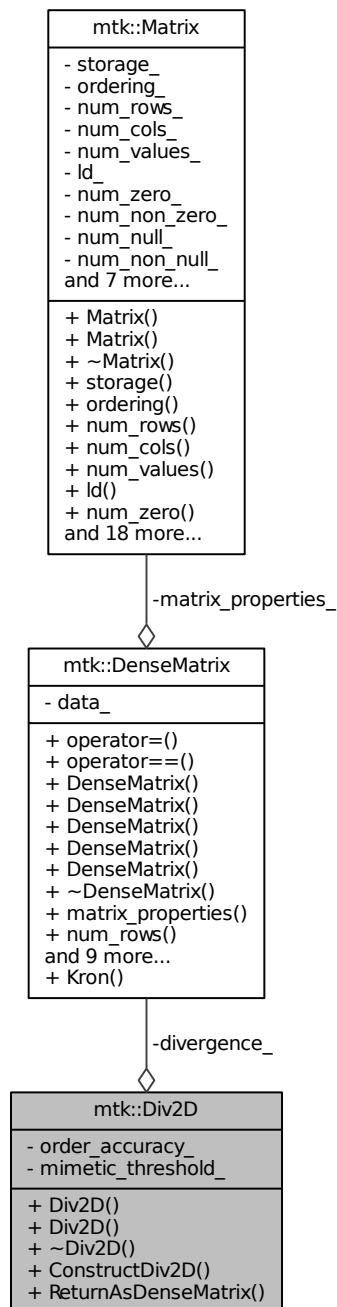
- [include/mtk_div_1d.h](#)

- [src/mtk_div_1d.cc](#)

16.6 mtk::Div2D Class Reference

```
#include <mtk_div_2d.h>
```

Collaboration diagram for mtk::Div2D:



Public Member Functions

- [Div2D \(\)](#)

Default constructor.

- [Div2D](#) (const [Div2D](#) &div)

Copy constructor.

- [~Div2D](#) ()

Destructor.

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

Factory method implementing the CBS Algorithm to build operator.

- [DenseMatrix](#) [ReturnAsDenseMatrix](#) () const

Return the operator as a dense matrix.

Private Attributes

- [DenseMatrix](#) divergence_

Actual operator.

- int [order_accuracy_](#)

Order of accuracy.

- [Real](#) [mimetic_threshold_](#)

Mimetic Threshold.

16.6.1 Detailed Description

Definition at line 66 of file [mtk_div_2d.h](#).

16.6.2 Constructor & Destructor Documentation

16.6.2.1 mtk::Div2D::Div2D ()

Definition at line 69 of file [mtk_div_2d.cc](#).

16.6.2.2 mtk::Div2D::Div2D (const Div2D &div)

Parameters

in	div	Given divergence.
--------------------	---------------------	-------------------

Definition at line 73 of file [mtk_div_2d.cc](#).

16.6.2.3 mtk::Div2D::~~Div2D ()

Definition at line 77 of file [mtk_div_2d.cc](#).

16.6.3 Member Function Documentation

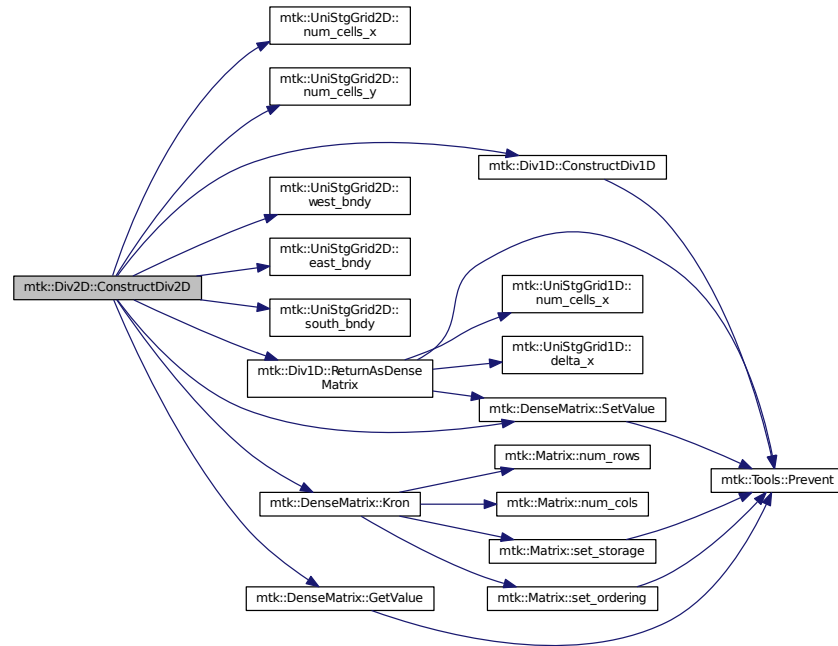
16.6.3.1 bool mtk::Div2D::ConstructDiv2D (const UniStgGrid2D &grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 79 of file [mtk_div_2d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Returns

The operator as a dense matrix.

Definition at line 145 of file [mtk_div_2d.cc](#).

Here is the caller graph for this function:

**16.6.4 Member Data Documentation****16.6.4.1 DenseMatrix mtk::Div2D::divergence_ [private]**

Definition at line 98 of file [mtk_div_2d.h](#).

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

Definition at line 102 of file [mtk_div_2d.h](#).

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

Definition at line 100 of file [mtk_div_2d.h](#).

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

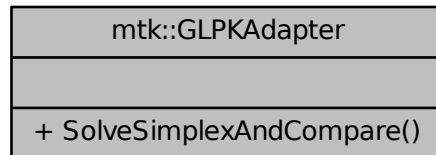
- [include/mtk_div_2d.h](#)
- [src/mtk_div_2d.cc](#)

16.7 mtk::GLPKAdapter Class Reference

Adapter class for the GLPK API.

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

Collaboration diagram for mtk::GLPKAdapter:



Static Public Member Functions

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

16.7.1 Detailed Description

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

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

Warning

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

See also

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

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

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

16.7.2 Member Function Documentation

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

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

Parameters

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

Returns

Relative error computed between attained solution and provided ref.

Warning

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

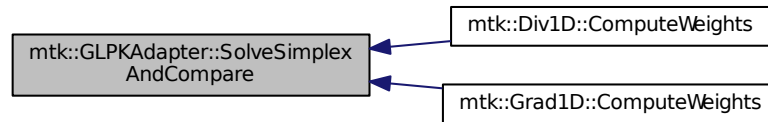
1. Memory allocation.
2. Fill the problem.
3. Copy the row to the vector objective.
4. Forming the RHS.
5. Setting up the objective function.
6. Setting up constraints.
7. Copy the matrix minus the row objective to the glpk problem.
8. Solve problem.

Definition at line 76 of file [mtk_glpk_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

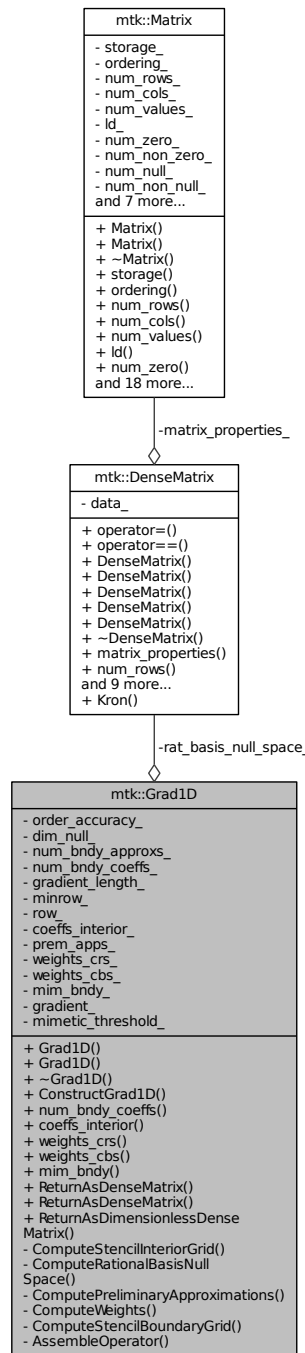
- [include/mtk_glpk_adapter.h](#)
- [src/mtk_glpk_adapter.cc](#)

16.8 mtk::Grad1D Class Reference

Implements a 1D mimetic gradient operator.

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

Collaboration diagram for mtk::Grad1D:



Public Member Functions

- [Grad1D \(\)](#)

- *Default constructor.*
- [Grad1D](#) (const [Grad1D](#) &grad)
- *Copy constructor.*
- [~Grad1D](#) ()
- *Destructor.*
- bool [ConstructGrad1D](#) (int order_accuracy=[kDefaultOrderAccuracy](#), [Real](#) mimetic_threshold=[kDefaultMimeticThreshold](#))
- *Factory method implementing the CBS Algorithm to build operator.*
- int [num_bndy_coeffs](#) () const
- *Returns how many coefficients are approximating at the boundary.*
- [Real](#) * [coeffs_interior](#) () const
- *Returns coefficients for the interior of the grid.*
- [Real](#) * [weights_crs](#) (void) const
- *Returns collection of weights as computed by the CRSA.*
- [Real](#) * [weights_cbs](#) (void) const
- *Returns collection of weights as computed by the CBSA.*
- [DenseMatrix](#) [mim_bndy](#) () const
- *Return collection of mimetic approximations at the boundary.*
- [DenseMatrix](#) [ReturnAsDenseMatrix](#) ([Real](#) west, [Real](#) east, int num_cells_x) const
- *Returns the operator as a dense matrix.*
- [DenseMatrix](#) [ReturnAsDenseMatrix](#) (const [UniStgGrid1D](#) &grid) const
- *Returns the operator as a dense matrix.*
- [DenseMatrix](#) [ReturnAsDimensionlessDenseMatrix](#) (int num_cells_x) const
- *Returns the operator as a dimensionless dense matrix.*

Private Member Functions

- bool [ComputeStencilInteriorGrid](#) (void)
- *Stage 1 of the CBS Algorithm.*
- bool [ComputeRationalBasisNullSpace](#) (void)
- *Stage 2.1 of the CBS Algorithm.*
- bool [ComputePreliminaryApproximations](#) (void)
- *Stage 2.2 of the CBS Algorithm.*
- bool [ComputeWeights](#) (void)
- *Stage 2.3 of the CBS Algorithm.*
- bool [ComputeStencilBoundaryGrid](#) (void)
- *Stage 2.4 of the CBS Algorithm.*
- bool [AssembleOperator](#) (void)
- *Stage 3 of the CBS Algorithm.*

Private Attributes

- int [order_accuracy_](#)
- *Order of numerical accuracy of the operator.*
- int [dim_null_](#)
- *Dim. null-space for boundary approximations.*
- int [num_bndy_approxs_](#)

- *Req. approximations at and near the boundary.*
- int [num_bndy_coeffs_](#)
Req. coeffs. per bndy pt. uni. order accuracy.
- int [gradient_length_](#)
Length of the output array.
- int [minrow_](#)
Row from the optimizer with the minimum rel. nor.
- int [row_](#)
Row currently processed by the optimizer.
- [DenseMatrix](#) [rat_basis_null_space_](#)
Rational b. null-space w. bndy.
- [Real](#) * [coeffs_interior_](#)
Interior stencil.
- [Real](#) * [prem_apps_](#)
2D array of boundary preliminary approximations.
- [Real](#) * [weights_crs_](#)
Array containing weights from CRSA.
- [Real](#) * [weights_cbs_](#)
Array containing weights from CBSA.
- [Real](#) * [mim_bndy_](#)
Array containing mimetic boundary approximations.
- [Real](#) * [gradient_](#)
Output array containing the operator and weights.
- [Real](#) [mimetic_threshold_](#)
< Mimetic threshold.

Friends

- std::ostream & [operator<<](#) (std::ostream &stream, [Grad1D](#) &in)
Output stream operator for printing.

16.8.1 Detailed Description

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

Definition at line 81 of file [mtk_grad_1d.h](#).

16.8.2 Constructor & Destructor Documentation

16.8.2.1 mtk::Grad1D::Grad1D ()

Definition at line 129 of file [mtk_grad_1d.cc](#).

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

Parameters

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

Definition at line 145 of file [mtk_grad_1d.cc](#).

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

Definition at line 161 of file [mtk_grad_1d.cc](#).

16.8.3 Member Function Documentation

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

Construct the output array with the operator and its weights.

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

Definition at line 1499 of file [mtk_grad_1d.cc](#).

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

Returns

Coefficients for the interior of the grid.

Definition at line 330 of file [mtk_grad_1d.cc](#).

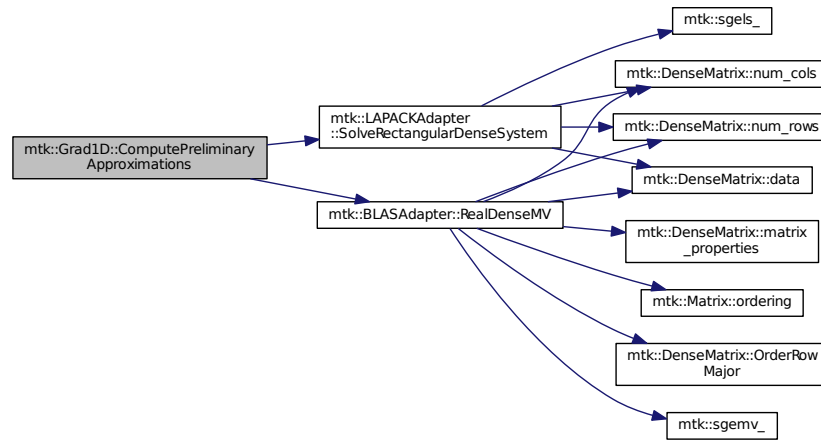
16.8.3.3 bool mtk::Grad1D::ComputePreliminaryApproximations (void) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

1. Create generator vector for the first approximation.
2. Compute the dim_null near-the-boundary columns of the pi matrix.
3. Create the Vandermonde matrix for this iteration.
4. New order-selector vector (gets re-written with LAPACK solutions).
5. Solving $\text{TT} * \text{rr} = \text{ob}$ yields the columns 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 possess the bottom elements, we proceed with the scaling.

Definition at line 833 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



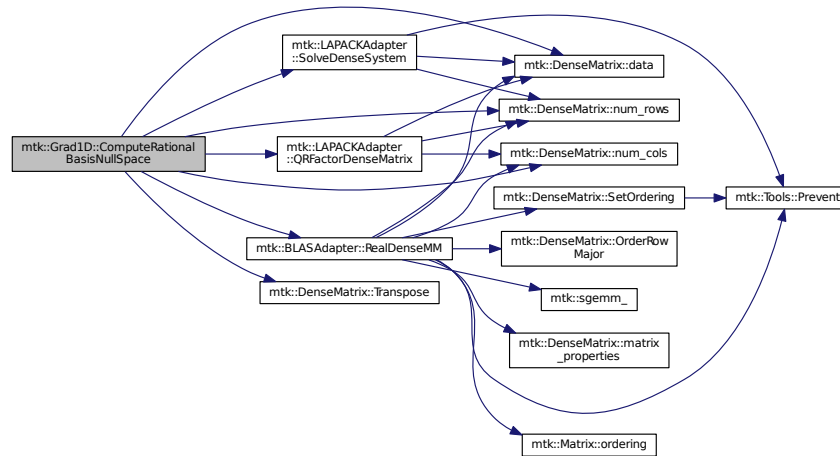
16.8.3.4 `bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) [private]`

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

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

Definition at line 650 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



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

Compute mimetic stencil approximating at boundary.

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

Definition at line 1393 of file [mtk_grad_1d.cc](#).

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

Compute the stencil approximating the interior of the staggered grid.

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

Definition at line 554 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



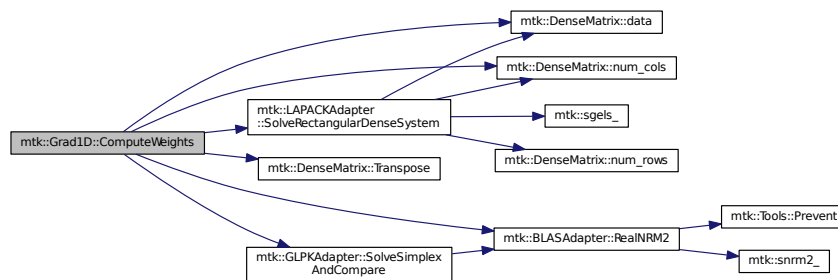
16.8.3.7 bool mtk::Grad1D::ComputeWeights (void) [private]

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

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

Definition at line 1053 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



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

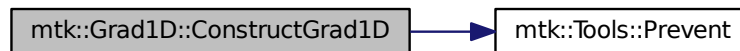
Returns

Success of the solution.

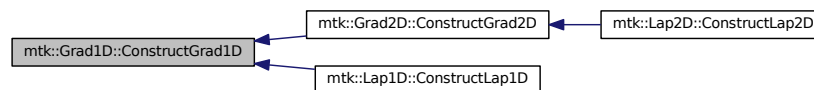
1. Compute stencil for the interior cells.
2. Compute a rational null-space from the first matrix transposed.
3. Compute preliminary approximation (non-mimetic) on the boundaries.
4. Compute quadrature weights to impose the mimetic conditions.
5. Compute real approximation (mimetic) on the boundaries.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

Definition at line 182 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



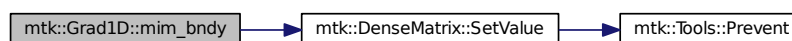
16.8.3.9 `mtk::DenseMatrix mtk::Grad1D::mim_bndy () const`

Returns

Collection of mimetic approximations at the boundary.

Definition at line 345 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



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

Returns

How many coefficients are approximating at the boundary.

Definition at line 325 of file [mtk_grad_1d.cc](#).

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

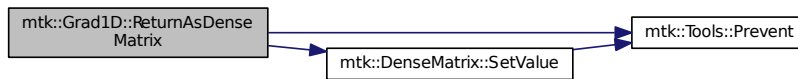
Returns

The operator as a dense matrix.

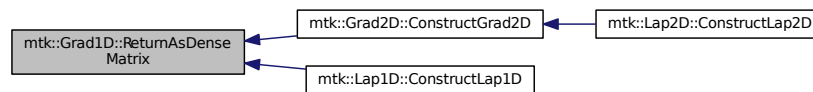
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 360 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

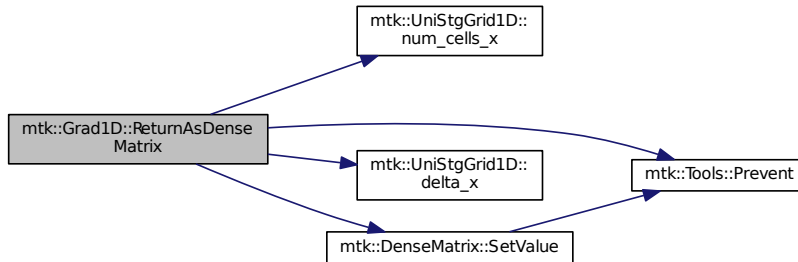
Returns

The operator as a dense matrix.

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

Definition at line 428 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



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

Returns

The operator as a dimensionless dense matrix.

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

Definition at line 492 of file [mtk_grad_1d.cc](#).

Here is the call graph for this function:



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

Returns

Collection of weights as computed by the CBSA.

Definition at line 340 of file [mtk_grad_1d.cc](#).

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

Returns

Success of the solution.

Definition at line 335 of file [mtk_grad_1d.cc](#).

16.8.4 Friends And Related Function Documentation

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

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

Definition at line 79 of file [mtk_grad_1d.cc](#).

16.8.5 Member Data Documentation

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

Definition at line 217 of file [mtk_grad_1d.h](#).

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

Definition at line 208 of file [mtk_grad_1d.h](#).

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

Definition at line 222 of file [mtk_grad_1d.h](#).

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

Definition at line 211 of file [mtk_grad_1d.h](#).

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

Definition at line 221 of file [mtk_grad_1d.h](#).

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

Definition at line 224 of file [mtk_grad_1d.h](#).

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

Definition at line 212 of file [mtk_grad_1d.h](#).

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

Definition at line 209 of file [mtk_grad_1d.h](#).

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

Definition at line 210 of file [mtk_grad_1d.h](#).

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

Definition at line 207 of file [mtk_grad_1d.h](#).

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

Definition at line 218 of file [mtk_grad_1d.h](#).

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

Definition at line 215 of file [mtk_grad_1d.h](#).

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

Definition at line 213 of file [mtk_grad_1d.h](#).

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

Definition at line 220 of file [mtk_grad_1d.h](#).

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

Definition at line 219 of file [mtk_grad_1d.h](#).

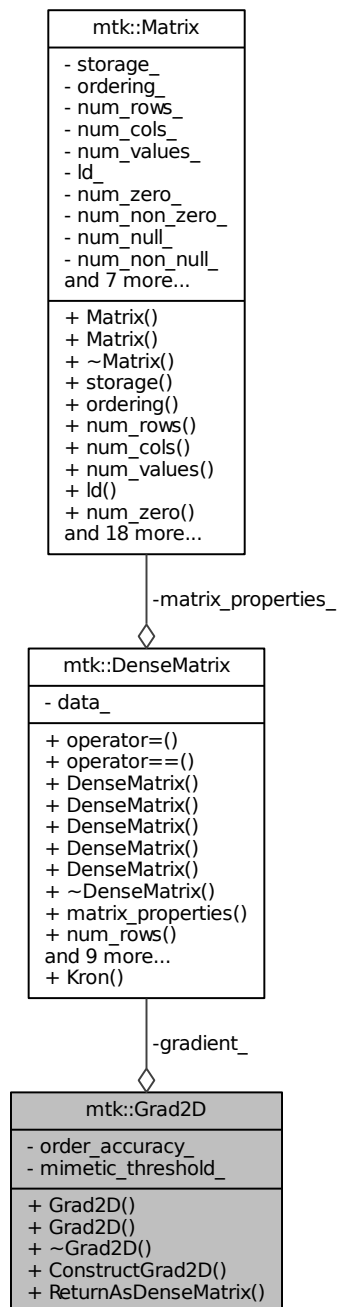
The documentation for this class was generated from the following files:

- [include/mtk_grad_1d.h](#)
- [src/mtk_grad_1d.cc](#)

16.9 mtk::Grad2D Class Reference

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

Collaboration diagram for mtk::Grad2D:



Public Member Functions

- [Grad2D](#) ()

Default constructor.

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

Copy constructor.

- [~Grad2D](#) ()

Destructor.

- bool [ConstructGrad2D](#) (const [UniStgGrid2D](#) &grid, int order_accuracy=kDefaultOrderAccuracy, [Real](#) mimetic_↔ threshold=kDefaultMimeticThreshold)

Factory method implementing the CBS Algorithm to build operator.

- [DenseMatrix](#) [ReturnAsDenseMatrix](#) () const

Return the operator as a dense matrix.

Private Attributes

- [DenseMatrix](#) gradient_

Actual operator.

- int [order_accuracy_](#)

Order of accuracy.

- [Real](#) [mimetic_threshold_](#)

Mimetic Threshold.

16.9.1 Detailed Description

Definition at line 66 of file [mtk_grad_2d.h](#).

16.9.2 Constructor & Destructor Documentation

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

Definition at line 67 of file [mtk_grad_2d.cc](#).

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

Parameters

in	div	Given divergence.
--------------------	---------------------	-------------------

Definition at line 71 of file [mtk_grad_2d.cc](#).

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

Definition at line 75 of file [mtk_grad_2d.cc](#).

16.9.3 Member Function Documentation

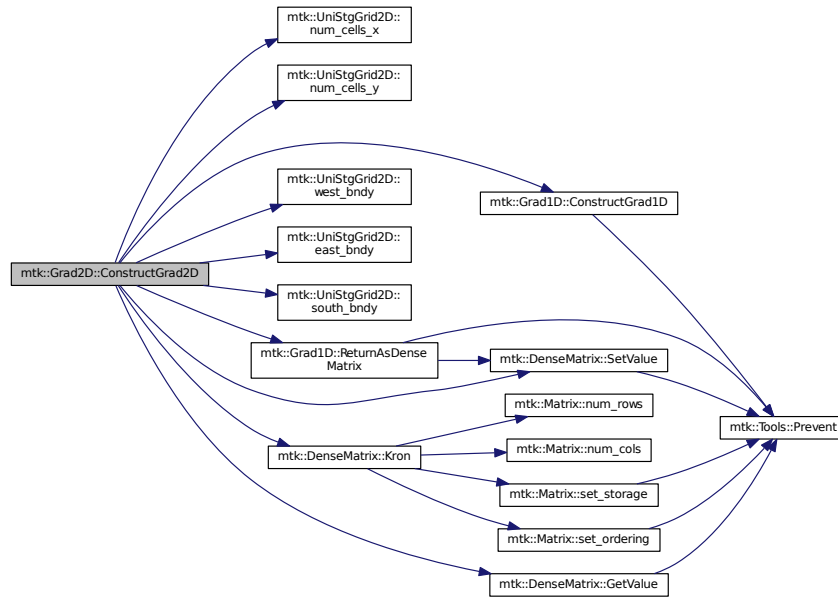
16.9.3.1 bool [mtk::Grad2D::ConstructGrad2D](#) (const [UniStgGrid2D](#) &grid, int order_accuracy = kDefaultOrderAccuracy, [mtk::Real](#) mimetic_threshold = kDefaultMimeticThreshold)

Returns

Success of the construction.

Definition at line 77 of file [mtk_grad_2d.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Returns

The operator as a dense matrix.

Definition at line 143 of file [mtk_grad_2d.cc](#).

Here is the caller graph for this function:

**16.9.4 Member Data Documentation****16.9.4.1 DenseMatrix mtk::Grad2D::gradient_ [private]**

Definition at line 98 of file [mtk_grad_2d.h](#).

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

Definition at line 102 of file [mtk_grad_2d.h](#).

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

Definition at line 100 of file [mtk_grad_2d.h](#).

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

- [include/mtk_grad_2d.h](#)
- [src/mtk_grad_2d.cc](#)

16.10 mtk::Interp1D Class Reference

Implements a 1D interpolation operator.

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

Collaboration diagram for mtk::Interp1D:

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

Public Member Functions

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

Private Attributes

- [DirInterp](#) dir_interp_
Direction of interpolation.
- int [order_accuracy_](#)
Order of numerical accuracy of the operator.
- [Real](#) * [coeffs_interior_](#)
Interior stencil.

Friends

- std::ostream & [operator<<](#) (std::ostream &stream, [Interp1D](#) &in)
Output stream operator for printing.

16.10.1 Detailed Description

This class implements a 1D interpolation operator.

Definition at line 82 of file [mtk_interp_1d.h](#).

16.10.2 Constructor & Destructor Documentation

16.10.2.1 `mtk::Interp1D::Interp1D ()`

Definition at line 80 of file [mtk_interp_1d.cc](#).

16.10.2.2 `mtk::Interp1D::Interp1D (const Interp1D & interp)`

Parameters

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

Definition at line 85 of file [mtk_interp_1d.cc](#).

16.10.2.3 `mtk::Interp1D::~~Interp1D ()`

Definition at line 90 of file [mtk_interp_1d.cc](#).

16.10.3 Member Function Documentation

16.10.3.1 `mtk::Real * mtk::Interp1D::coeffs_interior () const`

Returns

Coefficients for the interior of the grid.

Definition at line 130 of file [mtk_interp_1d.cc](#).

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

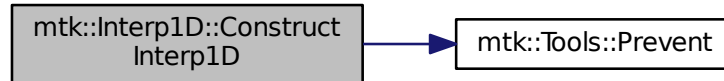
Returns

Success of the solution.

1. Compute stencil for the interior cells.

Definition at line 96 of file [mtk_interp_1d.cc](#).

Here is the call graph for this function:



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

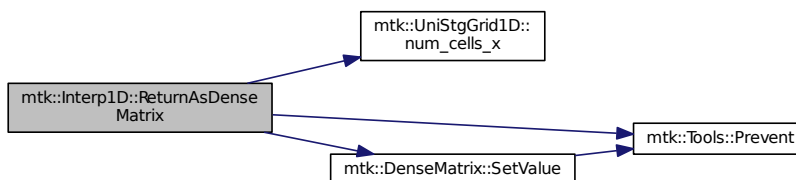
Returns

The operator as a dense matrix.

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

Definition at line 135 of file [mtk_interp_1d.cc](#).

Here is the call graph for this function:



16.10.4 Friends And Related Function Documentation

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

1. Print approximating coefficients for the interior.

Definition at line 66 of file [mtk_interp_1d.cc](#).

16.10.5 Member Data Documentation

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

Definition at line 127 of file [mtk_interp_1d.h](#).

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

Definition at line 123 of file [mtk_interp_1d.h](#).

16.10.5.3 **int** `mtk::Interp1D::order_accuracy_` `[private]`

Definition at line 125 of file [mtk_interp_1d.h](#).

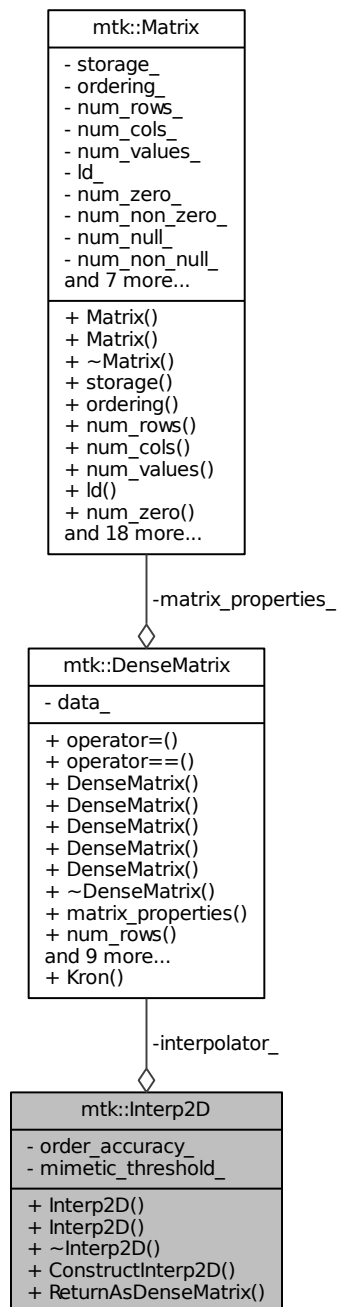
The documentation for this class was generated from the following files:

- [include/mtk_interp_1d.h](#)
- [src/mtk_interp_1d.cc](#)

16.11 `mtk::Interp2D` Class Reference

```
#include <mtk_interp_2d.h>
```

Collaboration diagram for mtk::Interp2D:



Public Member Functions

- [Interp2D\(\)](#)

Default constructor.

- [Interp2D](#) (const [Interp2D](#) &interp)

Copy constructor.

- [~Interp2D](#) ()

Destructor.

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

Factory method implementing the CBS Algorithm to build operator.

- [DenseMatrix ReturnAsDenseMatrix](#) ()

Return the operator as a dense matrix.

Private Attributes

- [DenseMatrix interpolator_](#)

Actual operator.

- int [order_accuracy_](#)

Order of accuracy.

- [Real mimetic_threshold_](#)

Mimetic Threshold.

16.11.1 Detailed Description

Definition at line 67 of file [mtk_interp_2d.h](#).

16.11.2 Constructor & Destructor Documentation

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

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

Parameters

in	lap	Given Laplacian.
--------------------	---------------------	------------------

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

16.11.3 Member Function Documentation

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

Returns

Success of the construction.

16.11.3.2 DenseMatrix mtk::Interp2D::ReturnAsDenseMatrix ()

Returns

The operator as a dense matrix.

16.11.4 Member Data Documentation

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

Definition at line 99 of file [mtk_interp_2d.h](#).

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

Definition at line 103 of file [mtk_interp_2d.h](#).

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

Definition at line 101 of file [mtk_interp_2d.h](#).

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

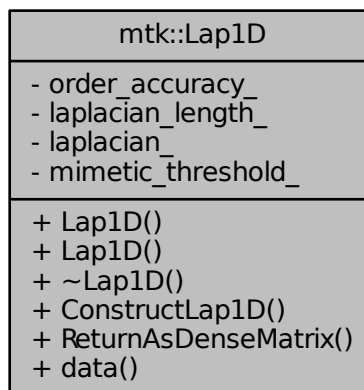
- [include/mtk_interp_2d.h](#)

16.12 mtk::Lap1D Class Reference

Implements a 1D mimetic Laplacian operator.

```
#include <mtk_lap_1d.h>
```

Collaboration diagram for mtk::Lap1D:



Public Member Functions

- [Lap1D](#) ()
Default constructor.
- [Lap1D](#) (const [Lap1D](#) &lap)
Copy constructor.
- [~Lap1D](#) ()
Destructor.
- bool [ConstructLap1D](#) (int order_accuracy=kDefaultOrderAccuracy, [Real](#) mimetic_threshold=kDefaultMimeticThreshold)
Factory method implementing the CBS Algorithm to build operator.
- [DenseMatrix ReturnAsDenseMatrix](#) (const [UniStgGrid1D](#) &grid) const
Return the operator as a dense matrix.
- const [mtk::Real](#) * [data](#) (const [UniStgGrid1D](#) &grid) const
Return the operator as a dense array.

Private Attributes

- int [order_accuracy_](#)
Order of numerical accuracy of the operator.
- int [laplacian_length_](#)
Length of the output array.
- [Real](#) * [laplacian_](#)
Output array containing the operator and weights.
- [Real](#) [mimetic_threshold_](#)
< Mimetic threshold.

Friends

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

16.12.1 Detailed Description

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

Definition at line 76 of file [mtk_lap_1d.h](#).

16.12.2 Constructor & Destructor Documentation

16.12.2.1 [mtk::Lap1D::Lap1D](#) ()

Definition at line 108 of file [mtk_lap_1d.cc](#).

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

Parameters

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

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

Definition at line 113 of file [mtk_lap_1d.cc](#).

16.12.3 Member Function Documentation

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

Returns

Success of the solution.

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

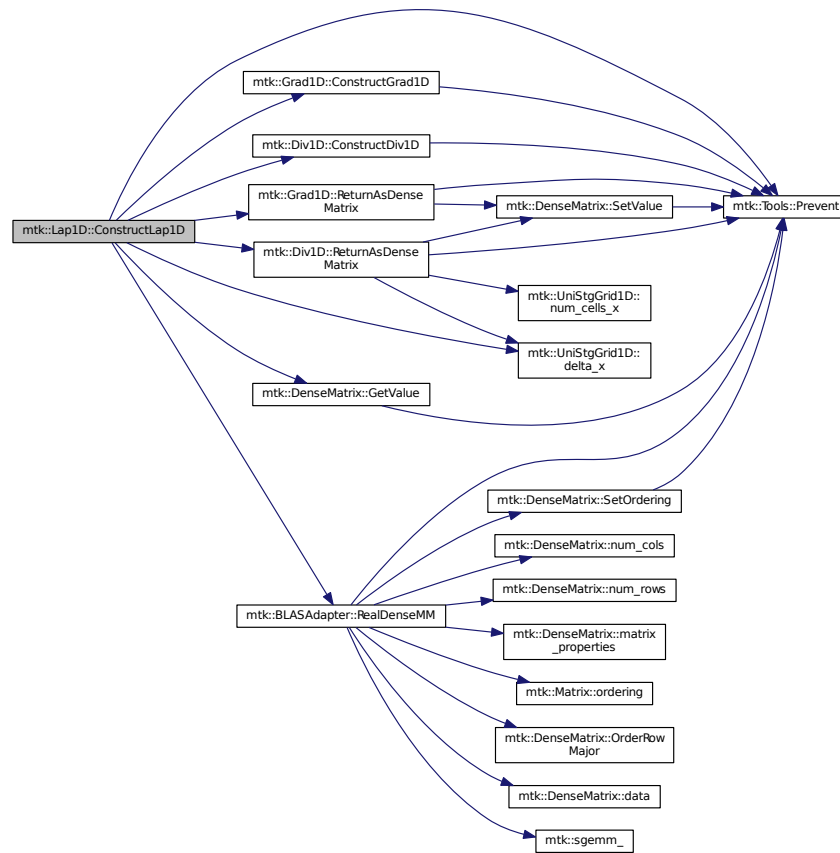
Warning

We do not compute weights for this operator.

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

Definition at line 119 of file [mtk_lap_1d.cc](#).

Here is the call graph for this function:



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

Returns

The operator as a dense array.

Definition at line 333 of file [mtk_lap_1d.cc](#).

Here is the call graph for this function:



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

Returns

The operator as a dense matrix.

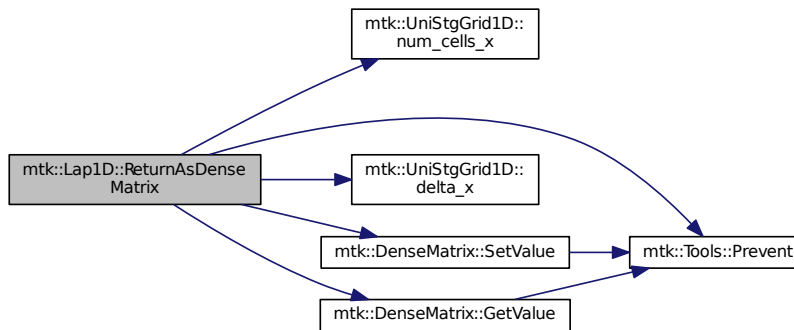
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

Note

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

Definition at line 265 of file [mtk_lap_1d.cc](#).

Here is the call graph for this function:



16.12.4 Friends And Related Function Documentation

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

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

Definition at line 73 of file [mtk_lap_1d.cc](#).

16.12.5 Member Data Documentation

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

Definition at line 120 of file [mtk_lap_1d.h](#).

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

Definition at line 118 of file [mtk_lap_1d.h](#).

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

Definition at line 122 of file [mtk_lap_1d.h](#).

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

Definition at line 117 of file [mtk_lap_1d.h](#).

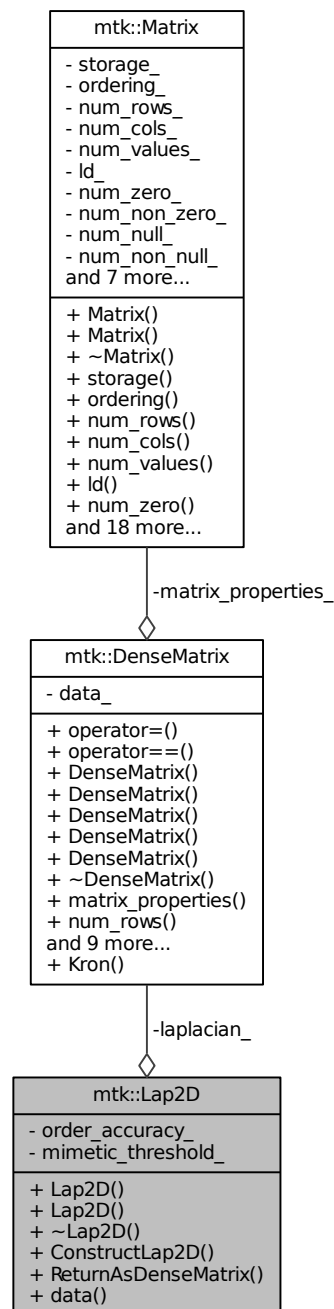
The documentation for this class was generated from the following files:

- [include/mtk_lap_1d.h](#)
- [src/mtk_lap_1d.cc](#)

16.13 mtk::Lap2D Class Reference

```
#include <mtk_lap_2d.h>
```

Collaboration diagram for mtk::Lap2D:



Public Member Functions

- [Lap2D\(\)](#)

Default constructor.

- [Lap2D](#) (const [Lap2D](#) &lap)

Copy constructor.

- [~Lap2D](#) ()

Destructor.

- bool [ConstructLap2D](#) (const [UniStgGrid2D](#) &grid, int order_accuracy=[kDefaultOrderAccuracy](#), [Real](#) mimetic_↔ threshold=[kDefaultMimeticThreshold](#))

Factory method implementing the CBS Algorithm to build operator.

- [DenseMatrix](#) [ReturnAsDenseMatrix](#) () const

Return the operator as a dense matrix.

- [Real](#) * [data](#) () const

Return the operator as a dense array.

Private Attributes

- [DenseMatrix](#) [laplacian_](#)

Actual operator.

- int [order_accuracy_](#)

Order of accuracy.

- [Real](#) [mimetic_threshold_](#)

Mimetic Threshold.

16.13.1 Detailed Description

Definition at line 66 of file [mtk_lap_2d.h](#).

16.13.2 Constructor & Destructor Documentation

16.13.2.1 [mtk::Lap2D::Lap2D](#) ()

Definition at line 69 of file [mtk_lap_2d.cc](#).

16.13.2.2 [mtk::Lap2D::Lap2D](#) (const [Lap2D](#) & lap)

Parameters

in	lap	Given Laplacian.
--------------------	---------------------	------------------

Definition at line 71 of file [mtk_lap_2d.cc](#).

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

Definition at line 75 of file [mtk_lap_2d.cc](#).

16.13.3 Member Function Documentation

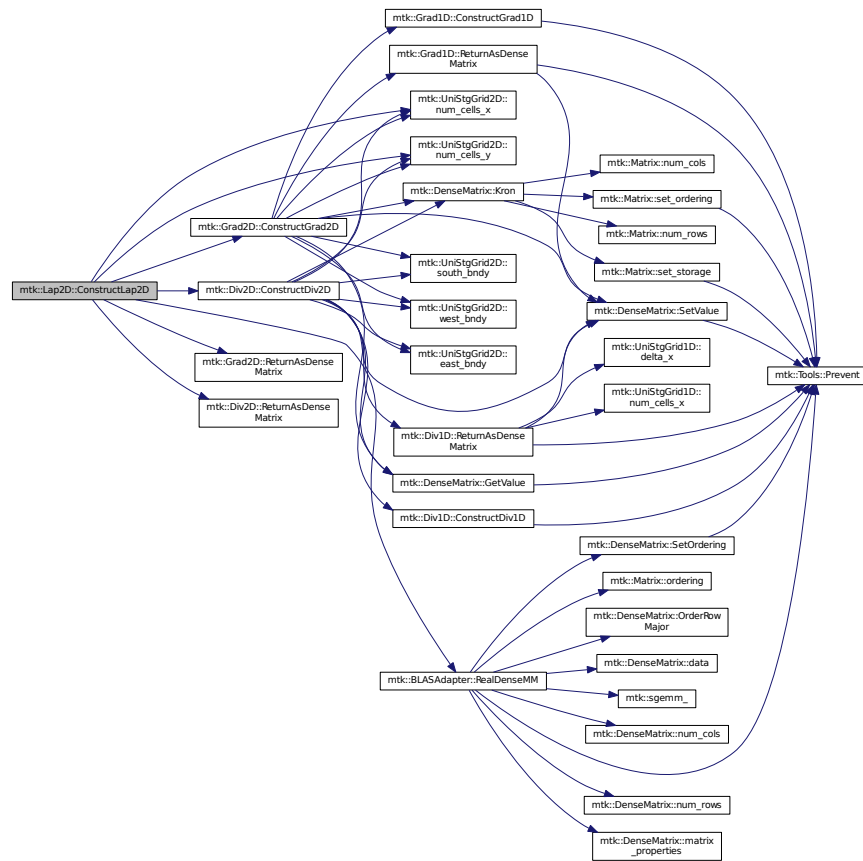
16.13.3.1 `bool mtk::Lap2D::ConstructLap2D (const UniStgGrid2D & grid, int order_accuracy = kDefaultOrderAccuracy, mtk::Real mimetic_threshold = kDefaultMimeticThreshold)`

Returns

Success of the construction.

Definition at line 77 of file [mtk_lap_2d.cc](#).

Here is the call graph for this function:



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

Returns

The operator as a dense array.

Definition at line 115 of file [mtk_lap_2d.cc](#).

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

Returns

The operator as a dense matrix.

Definition at line 110 of file [mtk_lap_2d.cc](#).

16.13.4 Member Data Documentation**16.13.4.1 DenseMatrix mtk::Lap2D::laplacian_ [private]**

Definition at line 105 of file [mtk_lap_2d.h](#).

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

Definition at line 109 of file [mtk_lap_2d.h](#).

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

Definition at line 107 of file [mtk_lap_2d.h](#).

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

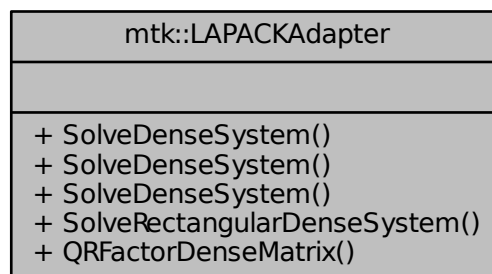
- [include/mtk_lap_2d.h](#)
- [src/mtk_lap_2d.cc](#)

16.14 mtk::LAPACKAdapter Class Reference

Adapter class for the LAPACK API.

```
#include <mtk_lapack_adapter.h>
```

Collaboration diagram for mtk::LAPACKAdapter:



Static Public Member Functions

- static int [SolveDenseSystem](#) (mtk::DenseMatrix &mm, mtk::Real *rhs)
Solves a dense system of linear equations.
- static int [SolveDenseSystem](#) (mtk::DenseMatrix &mm, mtk::DenseMatrix &rr)
Solves a dense system of linear equations.
- static int [SolveDenseSystem](#) (mtk::DenseMatrix &mm, mtk::UniStgGrid1D &rhs)
Solves a dense system of linear equations.
- static int [SolveRectangularDenseSystem](#) (const mtk::DenseMatrix &aa, mtk::Real *ob_, int ob_Id_)
Solves overdetermined or underdetermined real linear systems.
- static mtk::DenseMatrix [QRFactorDenseMatrix](#) (DenseMatrix &matrix)
Performs a QR factorization on a dense matrix.

16.14.1 Detailed Description

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

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

See also

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

Definition at line 92 of file [mtk_lapack_adapter.h](#).

16.14.2 Member Function Documentation

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

Adapts the MTK to LAPACK's routine.

Parameters

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

Returns

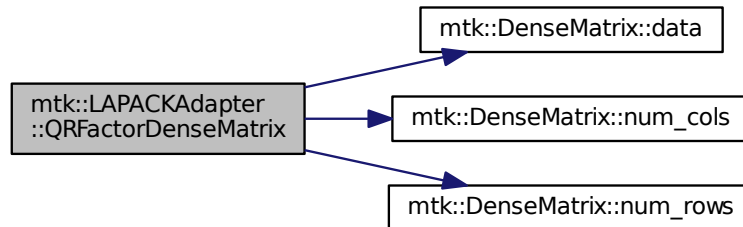
[Matrix Q](#).

Exceptions

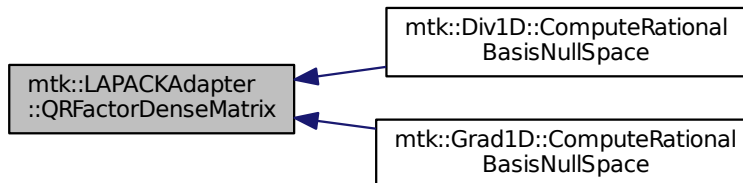
<i>std::bad_alloc</i>

Definition at line 555 of file [mtk_lapack_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

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

Parameters

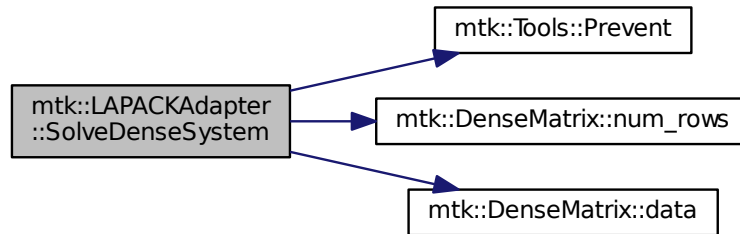
in	<i>matrix</i>	Input matrix.
in	<i>rhs</i>	Input right-hand sides vector.

Exceptions

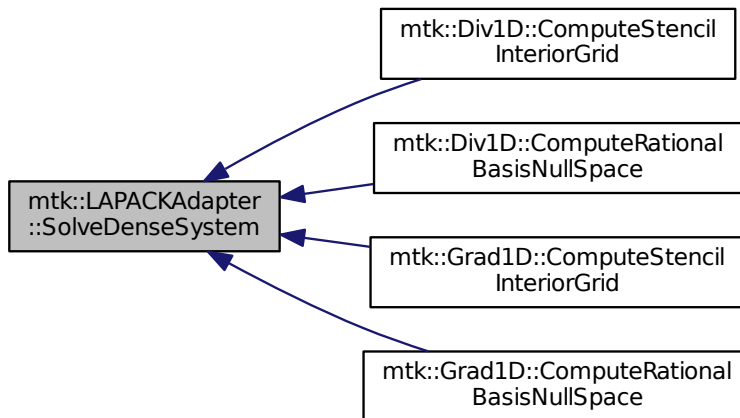
<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line [430](#) of file [mtk_lapack_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

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

Parameters

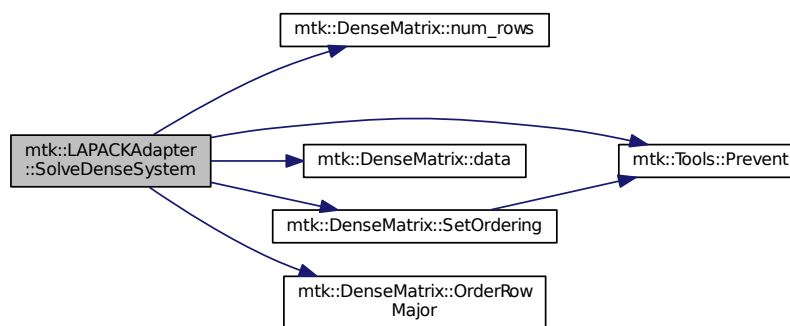
<code>in</code>	<code>matrix</code>	Input matrix.
<code>in</code>	<code>rr</code>	Input right-hand sides matrix.

Exceptions

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

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

Here is the call graph for this function:



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

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

Parameters

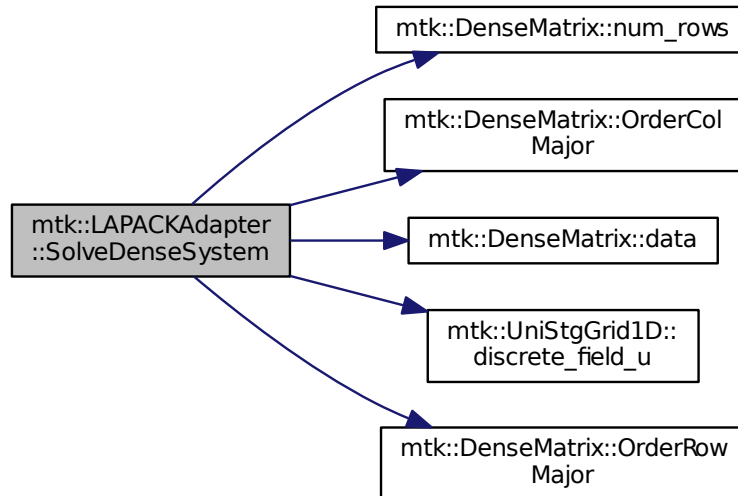
in	<i>matrix</i>	Input matrix.
in	<i>rr</i>	Input right-hand side from info on a grid.

Exceptions

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

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

Here is the call graph for this function:



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

Adapts the MTK to LAPACK's routine.

Parameters

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

Returns

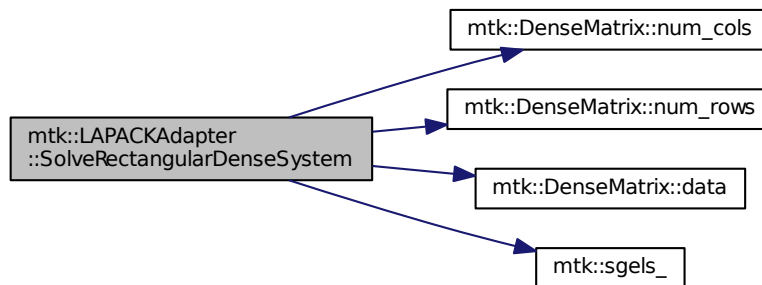
Success of the solution.

Exceptions

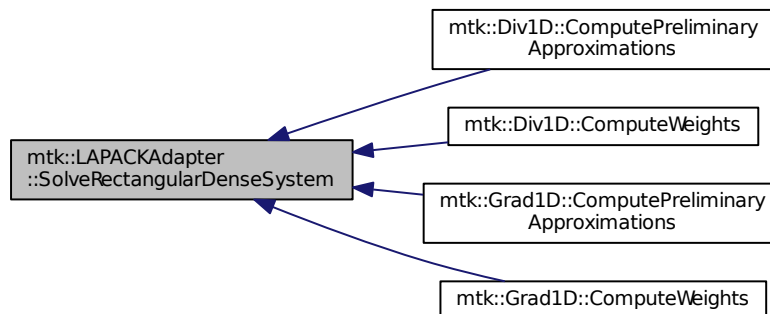
<code>std::bad_alloc</code>	
-----------------------------	--

Definition at line 756 of file [mtk_lapack_adapter.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

- [include/mtk_lapack_adapter.h](#)
- [src/mtk_lapack_adapter.cc](#)

16.15 mtk::Matrix Class Reference

Definition of the representation of a matrix in the MTK.


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

Collaboration diagram for mtk::Matrix:

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

Public Member Functions

- [Matrix](#) ()
Default constructor.
- [Matrix](#) (const [Matrix](#) &in)
Copy constructor.
- [~Matrix](#) ()
Destructor.
- [MatrixStorage](#) storage () const
Gets the type of storage of this matrix.
- [MatrixOrdering](#) ordering () const
Gets the type of ordering of this matrix.
- int [num_rows](#) () const
Gets the number of rows.
- int [num_cols](#) () const
Gets the number of rows.

- `int num_values () const`
Gets the number of values.
- `int ld () const`
Gets the matrix' leading dimension.
- `int num_zero () const`
Gets the number of zeros.
- `int num_non_zero () const`
Gets the number of non-zero values.
- `int num_null () const`
Gets the number of null values.
- `int num_non_null () const`
Gets the number of non-null values.
- `int kl () const`
Gets the number of lower diagonals.
- `int ku () const`
Gets the number of upper diagonals.
- `int bandwidth () const`
Gets the bandwidth.
- `Real abs_density () const`
Gets the absolute density.
- `Real rel_density () const`
Gets the relative density.
- `Real abs_sparsity () const`
Gets the Absolute sparsity.
- `Real rel_sparsity () const`
Gets the Relative sparsity.
- `void set_storage (const MatrixStorage &tt)`
Sets the storage type of the matrix.
- `void set_ordering (const MatrixOrdering &oo)`
Sets the ordering of the matrix.
- `void set_num_rows (int num_rows)`
Sets the number of rows of the matrix.
- `void set_num_cols (int num_cols)`
Sets the number of columns of the matrix.
- `void set_num_zero (int in)`
Sets the number of zero values of the matrix that matter.
- `void set_num_null (int in)`
Sets the number of zero values of the matrix that DO NOT matter.
- `void IncreaseNumZero ()`
Increases the number of values that equal zero but with meaning.
- `void IncreaseNumNull ()`
Increases the number of values that equal zero but with no meaning.

Private Attributes

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

16.15.1 Detailed Description

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

Definition at line 75 of file [mtk_matrix.h](#).

16.15.2 Constructor & Destructor Documentation

16.15.2.1 mtk::Matrix::Matrix ()

Definition at line 67 of file [mtk_matrix.cc](#).

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

Parameters

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

Definition at line 86 of file [mtk_matrix.cc](#).

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

Definition at line 105 of file [mtk_matrix.cc](#).

16.15.3 Member Function Documentation

16.15.3.1 Real mtk::Matrix::abs_density () const

See also

http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Absolute density of the matrix.

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

See also

http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Absolute sparsity of the matrix.

Definition at line 177 of file [mtk_matrix.cc](#).

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

Returns

Bandwidth of the matrix.

Definition at line 167 of file [mtk_matrix.cc](#).

16.15.3.4 void mtk::Matrix::IncreaseNumNull ()

Todo Review the definition of sparse matrices properties.

Definition at line 274 of file [mtk_matrix.cc](#).

16.15.3.5 void mtk::Matrix::IncreaseNumZero ()

Todo Review the definition of sparse matrices properties.

Definition at line 264 of file [mtk_matrix.cc](#).

16.15.3.6 int mtk::Matrix::kl () const

Returns

Number of lower diagonals.

Definition at line 157 of file [mtk_matrix.cc](#).

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

Returns

Number of upper diagonals.

Definition at line 162 of file [mtk_matrix.cc](#).

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

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

Returns

Leading dimension of the matrix.

Definition at line 132 of file [mtk_matrix.cc](#).

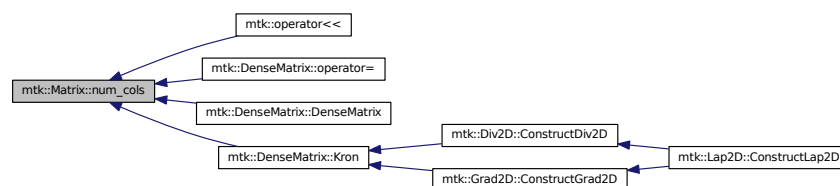
16.15.3.9 int mtk::Matrix::num_cols () const

Returns

Number of rows of the matrix.

Definition at line 122 of file [mtk_matrix.cc](#).

Here is the caller graph for this function:



16.15.3.10 `int mtk::Matrix::num_non_null () const`

See also

http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Number of non-null values of the matrix.

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

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

Returns

Number of non-zero values of the matrix.

Definition at line 142 of file `mtk_matrix.cc`.

16.15.3.12 `int mtk::Matrix::num_null () const`

See also

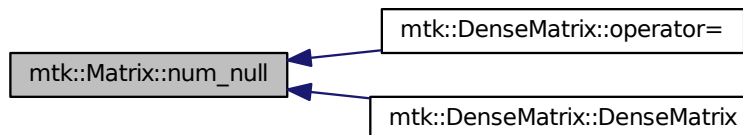
http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Number of null values of the matrix.

Definition at line 147 of file `mtk_matrix.cc`.

Here is the caller graph for this function:



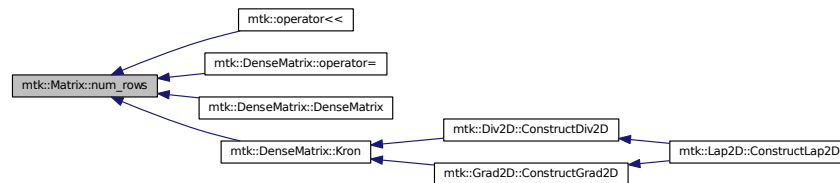
16.15.3.13 `int mtk::Matrix::num_rows () const`

Returns

Number of rows of the matrix.

Definition at line 117 of file [mtk_matrix.cc](#).

Here is the caller graph for this function:



16.15.3.14 int mtk::Matrix::num_values () const

Returns

Number of values of the matrix.

Definition at line 127 of file [mtk_matrix.cc](#).

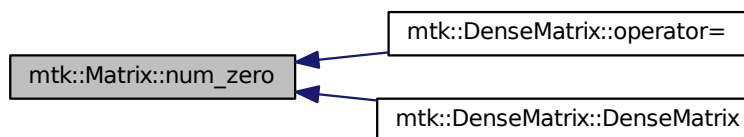
16.15.3.15 int mtk::Matrix::num_zero () const

Returns

Number of zeros of the matrix.

Definition at line 137 of file [mtk_matrix.cc](#).

Here is the caller graph for this function:



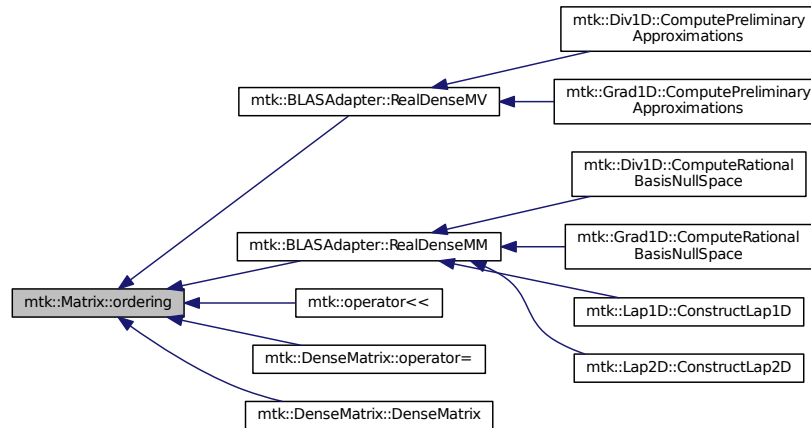
16.15.3.16 mtk::MatrixOrdering mtk::Matrix::ordering () const

Returns

Type of ordering of this matrix.

Definition at line 112 of file [mtk_matrix.cc](#).

Here is the caller graph for this function:



16.15.3.17 mtk::Real mtk::Matrix::rel_density () const

See also

http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Relative density of the matrix.

Definition at line 172 of file [mtk_matrix.cc](#).

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

See also

http://www.csrc.sdsu.edu/research_reports/CSR2013-01.pdf

Returns

Relative sparsity of the matrix.

Definition at line 182 of file [mtk_matrix.cc](#).

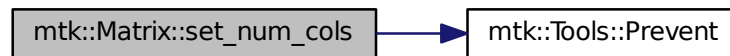
16.15.3.19 void mtk::Matrix::set_num_cols (int num_cols)

Parameters

<i>in</i>	<i>num_cols</i>	Number of columns.
-----------	-----------------	--------------------

Definition at line 224 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

Parameters

<i>in</i>	<i>in</i>	Number of zero values.
-----------	-----------	------------------------

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

Definition at line 250 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



16.15.3.21 `void mtk::Matrix::set_num_rows (int num_rows)`

Parameters

<code>in</code>	<code><i>num_rows</i></code>	Number of rows.
-----------------	------------------------------	-----------------

Definition at line 212 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



16.15.3.22 `void mtk::Matrix::set_num_zero (int in)`

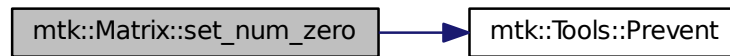
Parameters

<code>in</code>	<code><i>in</i></code>	Number of zero values.
-----------------	------------------------	------------------------

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

Definition at line 236 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

See also

[MatrixOrdering](#)

Parameters

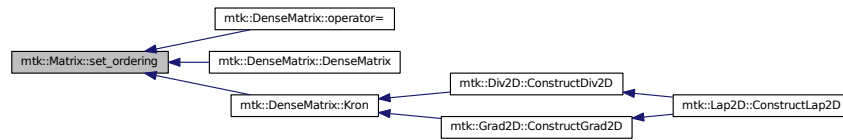
in	oo	Ordering of the matrix.
----	----	-------------------------

Definition at line 199 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



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

See also

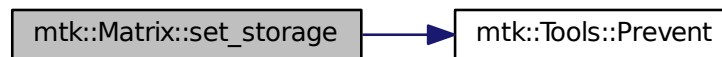
[MatrixStorage](#)

Parameters

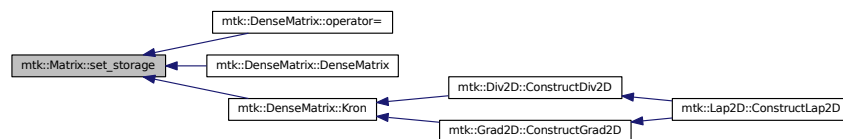
in	tt	Type of the matrix storage.
----	----	-----------------------------

Definition at line 187 of file [mtk_matrix.cc](#).

Here is the call graph for this function:



Here is the caller graph for this function:



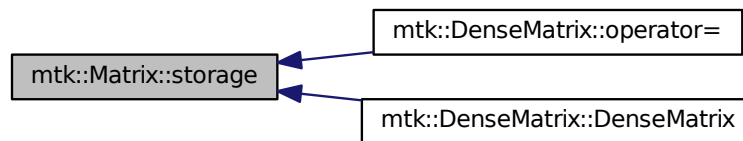
16.15.3.25 mtk::MatrixStorage mtk::Matrix::storage () const

Returns

Type of storage of this matrix.

Definition at line 107 of file [mtk_matrix.cc](#).

Here is the caller graph for this function:

**16.15.4 Member Data Documentation****16.15.4.1 Real mtk::Matrix::abs_density_ [private]**

Definition at line 296 of file [mtk_matrix.h](#).

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

Definition at line 298 of file [mtk_matrix.h](#).

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

Definition at line 294 of file [mtk_matrix.h](#).

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

Definition at line 292 of file [mtk_matrix.h](#).

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

Definition at line 293 of file [mtk_matrix.h](#).

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

Definition at line 285 of file [mtk_matrix.h](#).

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

Definition at line 283 of file [mtk_matrix.h](#).

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

Definition at line 290 of file [mtk_matrix.h](#).

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

Definition at line 288 of file [mtk_matrix.h](#).

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

Definition at line 289 of file [mtk_matrix.h](#).

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

Definition at line 282 of file [mtk_matrix.h](#).

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

Definition at line 284 of file [mtk_matrix.h](#).

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

Definition at line 287 of file [mtk_matrix.h](#).

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

Definition at line 280 of file [mtk_matrix.h](#).

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

Definition at line 297 of file [mtk_matrix.h](#).

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

Definition at line 299 of file [mtk_matrix.h](#).

16.15.4.17 **MatrixStorage** `mtk::Matrix::storage_` [private]

Definition at line 278 of file [mtk_matrix.h](#).

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

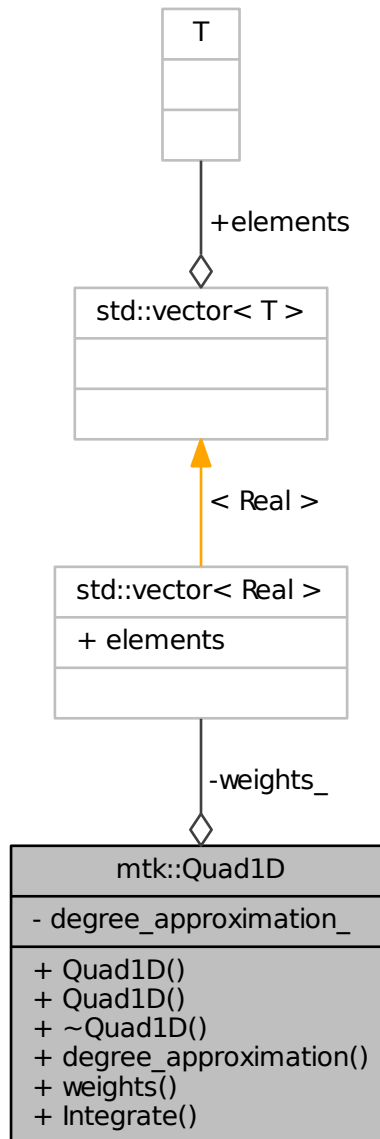
- [include/mtk_matrix.h](#)
- [src/mtk_matrix.cc](#)

16.16 mtk::Quad1D Class Reference

Implements a 1D mimetic quadrature.

```
#include <mtk_quad_1d.h>
```

Collaboration diagram for mtk::Quad1D:



Public Member Functions

- [Quad1D](#) ()
Default constructor.
- [Quad1D](#) (const [Quad1D](#) &quad)
Copy constructor.
- [~Quad1D](#) ()
Destructor.
- int [degree_approximation](#) () const
Get the degree of interpolating polynomial per sub-interval of domain.
- [Real](#) * [weights](#) () const
Return collection of weights.
- [Real](#) [Integrate](#) ([Real](#)(*Integrand)([Real](#) xx), [UniStgGrid1D](#) grid) const
Mimetic integration routine.

Private Attributes

- int [degree_approximation_](#)
Degree of the interpolating polynomial.
- std::vector< [Real](#) > [weights_](#)
Collection of weights.

Friends

- std::ostream & [operator<<](#) (std::ostream &stream, [Quad1D](#) &in)
Output stream operator for printing.

16.16.1 Detailed Description

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

Definition at line 81 of file [mtk_quad_1d.h](#).

16.16.2 Constructor & Destructor Documentation

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

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

Parameters

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

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

16.16.3 Member Function Documentation

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

Returns

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

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

Parameters

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

Returns

Result of the integration.

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

Returns

Collection of weights.

16.16.4 Friends And Related Function Documentation

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

16.16.5 Member Data Documentation

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

Definition at line 124 of file [mtk_quad_1d.h](#).

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

Definition at line 126 of file [mtk_quad_1d.h](#).

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

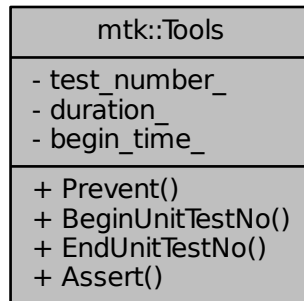
- [include/mtk_quad_1d.h](#)

16.17 mtk::Tools Class Reference

Tool manager class.

```
#include <mtk_tools.h>
```

Collaboration diagram for mtk::Tools:



Static Public Member Functions

- static void [Prevent](#) (const bool complement, const char *fname, int lineno, const char *fxname)
Enforces preconditions by preventing their complements from occur.
- static void [BeginUnitTestNo](#) (const int &nn)
Begins the execution of a unit test. Starts a timer.
- static void [EndUnitTestNo](#) (const int &nn)
Ends the execution of a unit test. Stops and reports wall-clock time.
- static void [Assert](#) (const bool condition)
Asserts if the condition required to pass the unit test occurs.

Static Private Attributes

- static int [test_number_](#)
Current test being executed.
- static [Real](#) [duration_](#)
Duration of the current test.
- static clock_t [begin_time_](#)
Elapsed time on current test.

16.17.1 Detailed Description

Basic tools to ensure execution correctness.

Definition at line 78 of file [mtk_tools.h](#).

16.17.2 Member Function Documentation

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

Parameters

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

Definition at line 114 of file [mtk_tools.cc](#).

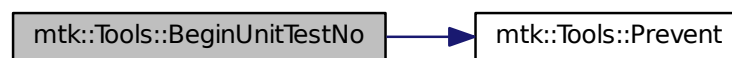
16.17.2.2 void mtk::Tools::BeginUnitTestNo (const int & *nn*) [static]

Parameters

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

Definition at line 91 of file [mtk_tools.cc](#).

Here is the call graph for this function:



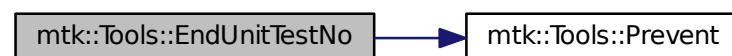
16.17.2.3 void mtk::Tools::EndUnitTestNo (const int & *nn*) [static]

Parameters

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

Definition at line 105 of file [mtk_tools.cc](#).

Here is the call graph for this function:



16.17.2.4 void mtk::Tools::Prevent (const bool *complement*, const char * *fname*, int *lineno*, const char * *fxname*) [static]

See also

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

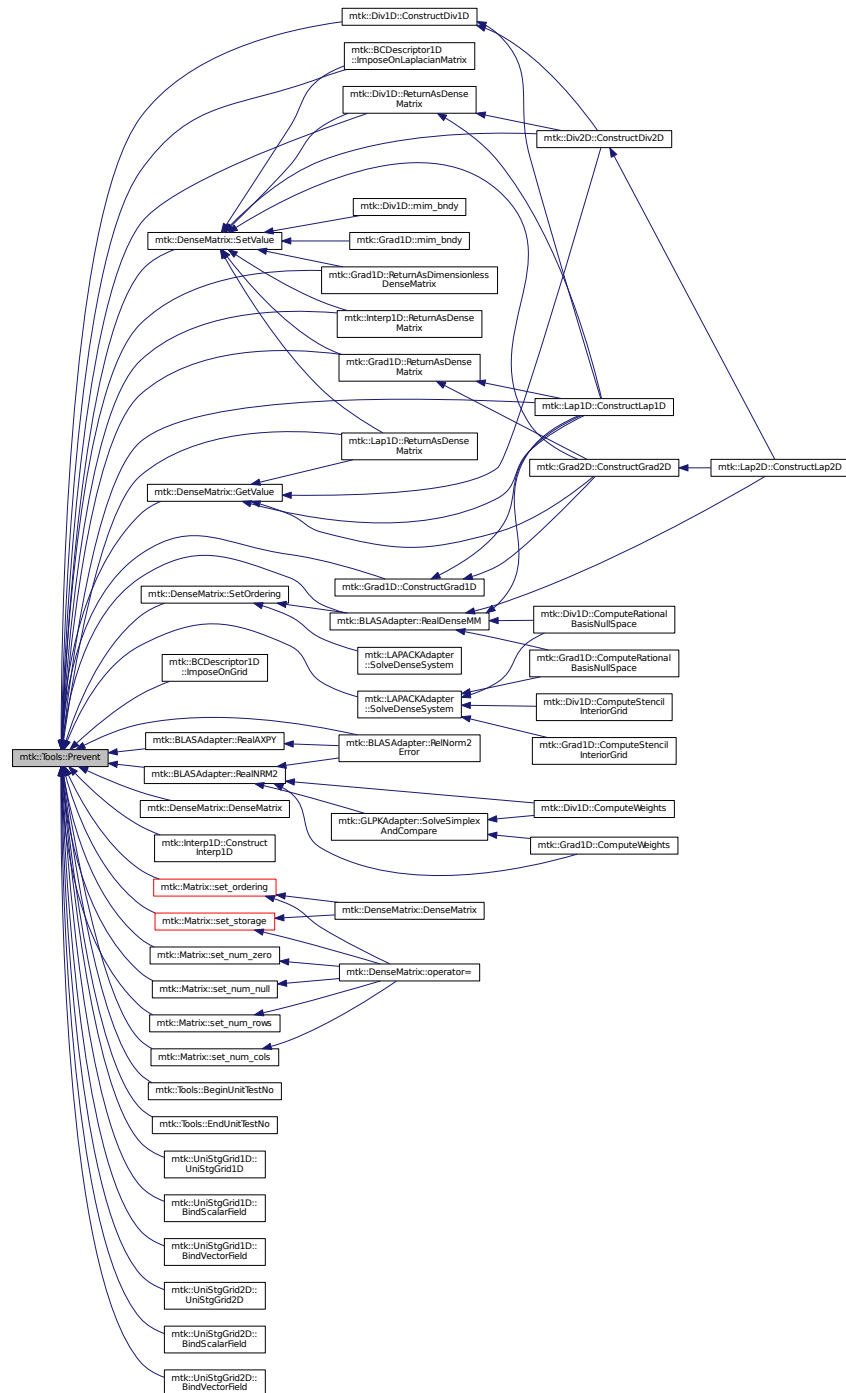
Parameters

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

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

Definition at line 61 of file [mtk_tools.cc](#).

Here is the caller graph for this function:



16.17.3 Member Data Documentation

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

Definition at line 121 of file [mtk_tools.h](#).

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

Definition at line 119 of file [mtk_tools.h](#).

16.17.3.3 `int mtk::Tools::test_number_` `[static], [private]`

Todo Check usage of static methods and private members.

Definition at line 117 of file [mtk_tools.h](#).

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

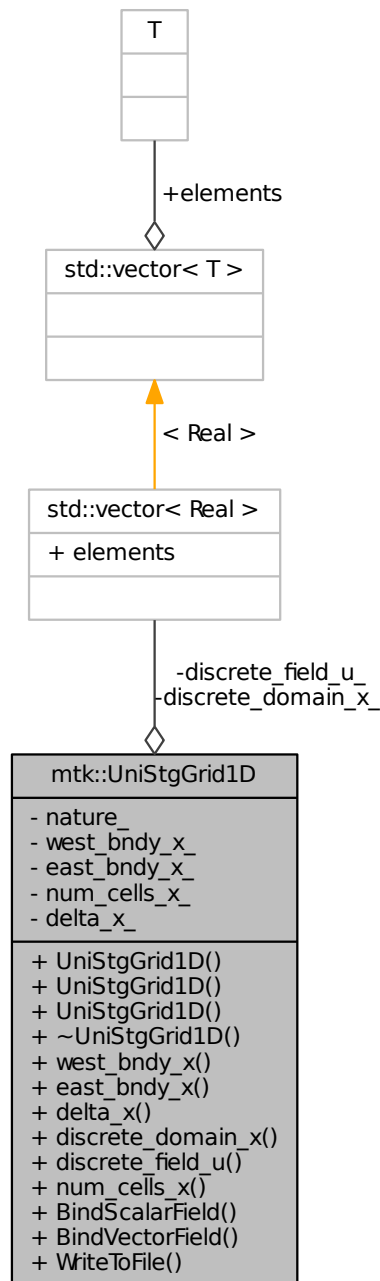
- [include/mtk_tools.h](#)
- [src/mtk_tools.cc](#)

16.18 mtk::UniStgGrid1D Class Reference

Uniform 1D Staggered Grid.

```
#include <mtk_uni_stg_grid_1d.h>
```

Collaboration diagram for `mtk::UniStgGrid1D`:



Public Member Functions

- [UniStgGrid1D \(\)](#)

Default constructor.

- [UniStgGrid1D](#) (const [UniStgGrid1D](#) &grid)

Copy constructor.

- [UniStgGrid1D](#) (const [Real](#) &west_bndy_x, const [Real](#) &east_bndy_x, const int &num_cells_x, const [mtk::Field](#) &nature &nature=[mtk::SCALAR](#))

Construct a grid based on spatial discretization parameters.

- [~UniStgGrid1D](#) ()

Destructor.

- [Real](#) west_bndy_x () const

Provides access to west boundary spatial coordinate.

- [Real](#) east_bndy_x () const

Provides access to east boundary spatial coordinate.

- [Real](#) delta_x () const

Provides access to the computed Δx .

- const [Real](#) * discrete_domain_x () const

Provides access to the grid spatial data.

- [Real](#) * discrete_field_u ()

Provides access to the grid field data.

- int num_cells_x () const

Provides access to the number of cells of the grid.

- void BindScalarField ([Real](#)(*ScalarField)([Real](#) xx))

Binds a given scalar field to the grid.

- void BindVectorField ([Real](#)(*VectorField)([Real](#) xx))

Binds a given vector field to the grid.

- bool WriteToFile (std::string filename, std::string space_name, std::string field_name) const

Writes grid to a file compatible with gnuplot 4.6.

Private Attributes

- [FieldNature](#) nature_

Nature of the discrete field.

- std::vector< [Real](#) > discrete_domain_x_

Array of spatial data.

- std::vector< [Real](#) > discrete_field_u_

Array of field's data.

- [Real](#) west_bndy_x_

West boundary spatial coordinate.

- [Real](#) east_bndy_x_

East boundary spatial coordinate.

- [Real](#) num_cells_x_

Number of cells discretizing the domain.

- [Real](#) delta_x_

Produced Δx .

Friends

- std::ostream & operator<< (std::ostream &stream, [UniStgGrid1D](#) &in)

Prints the grid as a tuple of arrays.

16.18.1 Detailed Description

Uniform 1D Staggered Grid.

Definition at line 77 of file [mtk_uni_stg_grid_1d.h](#).

16.18.2 Constructor & Destructor Documentation

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

Definition at line 99 of file [mtk_uni_stg_grid_1d.cc](#).

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

Parameters

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

Definition at line 108 of file [mtk_uni_stg_grid_1d.cc](#).

16.18.2.3 `mtk::UniStgGrid1D::UniStgGrid1D (const Real & west_bndy_x, const Real & east_bndy_x, const int & num_cells_x, const mtk::FieldNature & nature = mtk::SCALAR)`

Parameters

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

See also

[mtk::FieldNature](#)

Definition at line 124 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the call graph for this function:



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

Definition at line 144 of file [mtk_uni_stg_grid_1d.cc](#).

16.18.3 Member Function Documentation

16.18.3.1 void mtk::UniStgGrid1D::BindScalarField (*Real*(*)(*Real* xx) *ScalarField*)

Parameters

in	<i>ScalarField</i>	Pointer to the function implementing the scalar field.
----	--------------------	--

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

Definition at line 176 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the call graph for this function:



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

We assume the field to be of the form:

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

Parameters

in	<i>VectorField</i>	Pointer to the function implementing the vector field.
----	--------------------	--

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

Definition at line 212 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the call graph for this function:



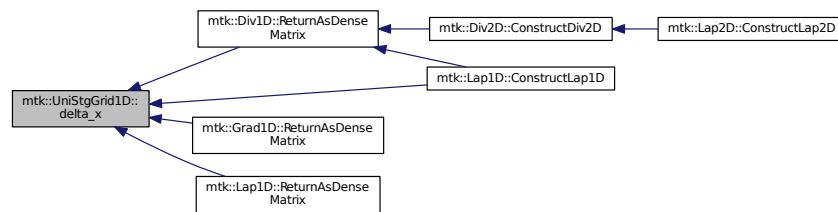
16.18.3.3 `mtk::Real mtk::UniStgGrid1D::delta_x () const`

Returns

Computed Δx .

Definition at line 156 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the caller graph for this function:



16.18.3.4 `const mtk::Real * mtk::UniStgGrid1D::discrete_domain_x () const`

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 161 of file [mtk_uni_stg_grid_1d.cc](#).

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

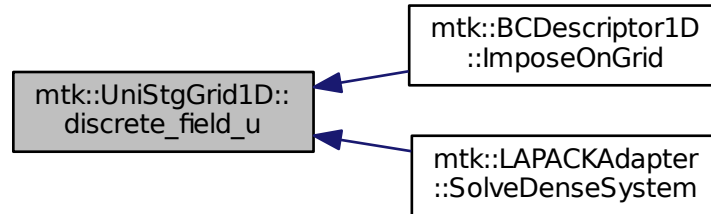
Returns

Pointer to the field data.

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

Definition at line 166 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the caller graph for this function:



16.18.3.6 mtk::Real mtk::UniStgGrid1D::east_bndy_x () const

Returns

East boundary spatial coordinate.

Definition at line 151 of file [mtk_uni_stg_grid_1d.cc](#).

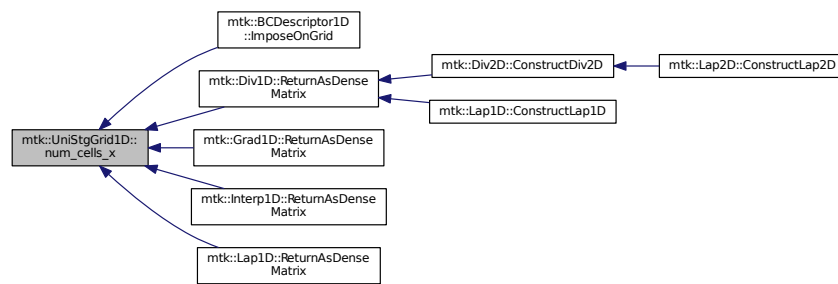
16.18.3.7 int mtk::UniStgGrid1D::num_cells_x () const

Returns

Number of cells of the grid.

Definition at line 171 of file [mtk_uni_stg_grid_1d.cc](#).

Here is the caller graph for this function:



16.18.3.8 `mtk::Real mtk::UniStgGrid1D::west_bndy_x () const`

Returns

West boundary spatial coordinate.

Definition at line 146 of file [mtk_uni_stg_grid_1d.cc](#).

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

Parameters

in	<i>filename</i>	Name of the output file.
in	<i>space_name</i>	Name for the first column of the data.
in	<i>field_name</i>	Name for the second column of the data.

Returns

Success of the file writing process.

See also

<http://www.gnuplot.info/>

Definition at line 240 of file [mtk_uni_stg_grid_1d.cc](#).

16.18.4 Friends And Related Function Documentation

16.18.4.1 `std::ostream& operator<< (std::ostream & stream, mtk::UniStgGrid1D & in) [friend]`

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

Definition at line 68 of file [mtk_uni_stg_grid_1d.cc](#).

16.18.5 Member Data Documentation

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

Definition at line 200 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 194 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 195 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 198 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 192 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 199 of file [mtk_uni_stg_grid_1d.h](#).

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

Definition at line 197 of file [mtk_uni_stg_grid_1d.h](#).

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

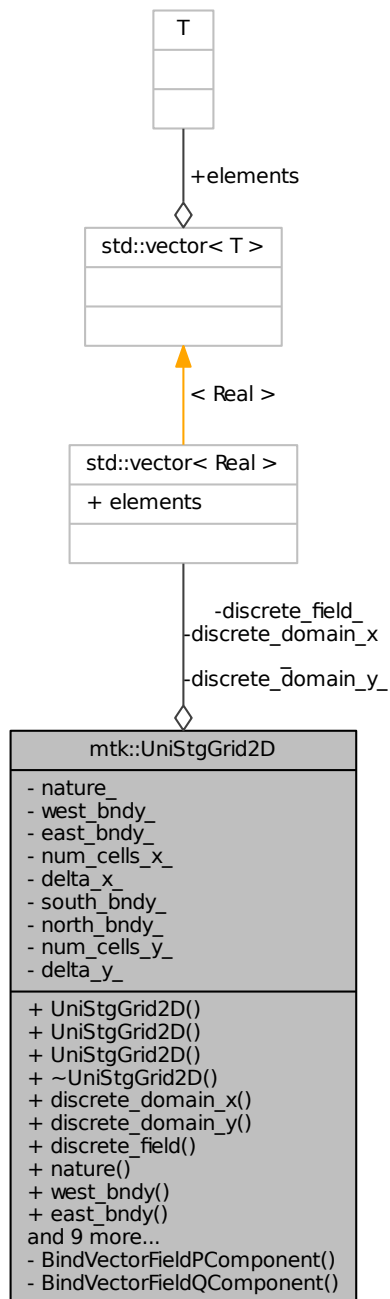
- [include/mtk_uni_stg_grid_1d.h](#)
- [src/mtk_uni_stg_grid_1d.cc](#)

16.19 mtk::UniStgGrid2D Class Reference

Uniform 2D Staggered Grid.

```
#include <mtk_uni_stg_grid_2d.h>
```

Collaboration diagram for `mtk::UniStgGrid2D`:



Public Member Functions

- [UniStgGrid2D](#) ()

Default constructor.

- `UniStgGrid2D (const UniStgGrid2D &grid)`

Copy constructor.

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

Construct a grid based on spatial discretization parameters.

- `~UniStgGrid2D ()`

Destructor.

- `const Real * discrete_domain_x () const`

Provides access to the grid spatial data.

- `const Real * discrete_domain_y () const`

Provides access to the grid spatial data.

- `const Real * discrete_field () const`

Provides access to the grid field data.

- `FieldNature nature () const`

Physical nature of the data bound to the grid.

- `Real west_bndy () const`

Provides access to west boundary spatial coordinate.

- `Real east_bndy () const`

Provides access to east boundary spatial coordinate.

- `int num_cells_x () const`

Provides access to the number of cells of the grid.

- `Real delta_x () const`

Provides access to the computed Δx .

- `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 Δy .

- `void BindScalarField (Real(*ScalarField)(Real xx, Real yy))`

Binds a given scalar field to the grid.

- `void BindVectorField (Real(*VectorFieldPComponent)(Real xx, Real yy), Real(*VectorFieldQComponent)(Real xx, Real yy))`

Binds a given vector field to the grid.

- `bool WriteToFile (std::string filename, std::string space_name_x, std::string space_name_y, std::string field_name) const`

Writes grid to a file compatible with Gnuplot 4.6.

Private Member Functions

- `void BindVectorFieldPComponent (Real(*VectorFieldPComponent)(Real xx, Real yy))`

Binds a given component of a vector field to the grid.

- `void BindVectorFieldQComponent (Real(*VectorFieldQComponent)(Real xx, Real yy))`

Binds a given component of a vector field to the grid.

Private Attributes

- `std::vector< Real > discrete_domain_x_`
Array of spatial data.
- `std::vector< Real > discrete_domain_y_`
Array of spatial data.
- `std::vector< Real > discrete_field_`
Array of field's data.
- `FieldNature nature_`
Nature of the discrete field.
- `Real west_bndy_`
West boundary spatial coordinate.
- `Real east_bndy_`
East boundary spatial coordinate.
- `int num_cells_x_`
Number of cells discretizing the domain.
- `Real delta_x_`
Computed 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.

16.19.1 Detailed Description

Uniform 2D Staggered Grid.

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

16.19.2 Constructor & Destructor Documentation

16.19.2.1 `mtk::UniStgGrid2D::UniStgGrid2D ()`

Definition at line 131 of file `mtk_uni_stg_grid_2d.cc`.

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

Parameters

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

Definition at line 145 of file [mtk_uni_stg_grid_2d.cc](#).

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

Parameters

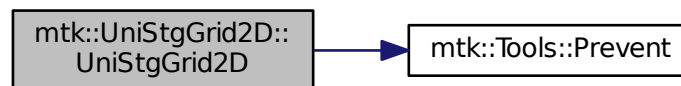
in	<i>west_bndy_x</i>	Coordinate for the west boundary.
in	<i>east_bndy_x</i>	Coordinate for the east boundary.
in	<i>num_cells_x</i>	Number of cells of the required grid.
in	<i>south_bndy_y</i>	Coordinate for the west boundary.
in	<i>north_bndy_y</i>	Coordinate for the east boundary.
in	<i>num_cells_y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

See also

[mtk::FieldNature](#)

Definition at line 169 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the call graph for this function:



16.19.2.4 **mtk::UniStgGrid2D::~~UniStgGrid2D** ()

Definition at line 203 of file [mtk_uni_stg_grid_2d.cc](#).

16.19.3 Member Function Documentation

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

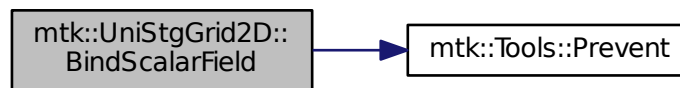
Parameters

in	<i>ScalarField</i>	Pointer to the function implementing the scalar field.
----	--------------------	--

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

Definition at line 265 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the call graph for this function:



16.19.3.2 void mtk::UniStgGrid2D::BindVectorField (Real(*) (Real xx, Real yy) VectorFieldPComponent, Real(*) (Real xx, Real yy) VectorFieldQComponent)

We assume the field to be of the form:

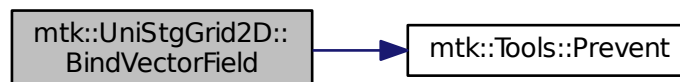
$$\mathbf{v}(x) = p(x,y)\hat{\mathbf{i}} + q(x,y)\hat{\mathbf{j}}$$

Parameters

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

Definition at line 408 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the call graph for this function:



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

We assume the field to be of the form:

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

Parameters

in	<i>BindVectorFieldPComponent</i>	Pointer to the function implementing the \$ p \$ component of the vector field.
----	----------------------------------	---

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

Definition at line 315 of file [mtk_uni_stg_grid_2d.cc](#).

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

We assume the field to be of the form:

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

Parameters

in	<i>BindVectorFieldQComponent</i>	Pointer to the function implementing the \$ q \$ component of the vector field.
----	----------------------------------	---

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

Definition at line 380 of file [mtk_uni_stg_grid_2d.cc](#).

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

Returns

Computed \$ x \$.

Definition at line 225 of file [mtk_uni_stg_grid_2d.cc](#).

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

Returns

Computed \$ y \$.

Definition at line 250 of file [mtk_uni_stg_grid_2d.cc](#).

16.19.3.7 `const mtk::Real * mtk::UniStgGrid2D::discrete_domain_x () const`

Returns

Pointer to the spatial data.

Todo Review const-correctness of the pointer we return.

Definition at line 230 of file [mtk_uni_stg_grid_2d.cc](#).

16.19.3.8 `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 255 of file [mtk_uni_stg_grid_2d.cc](#).

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

Returns

Pointer to the field data.

Definition at line 260 of file [mtk_uni_stg_grid_2d.cc](#).

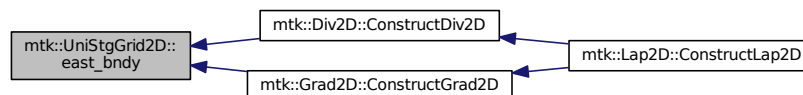
16.19.3.10 `mtk::Real mtk::UniStgGrid2D::east_bndy () const`

Returns

East boundary spatial coordinate.

Definition at line 215 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the caller graph for this function:



16.19.3.11 `mtk::FieldNature mtk::UniStgGrid2D::nature () const`

Returns

Value of an enumeration.

See also

[mtk::FieldNature](#)

Definition at line 205 of file [mtk_uni_stg_grid_2d.cc](#).

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

Returns

North boundary spatial coordinate.

Definition at line 240 of file [mtk_uni_stg_grid_2d.cc](#).

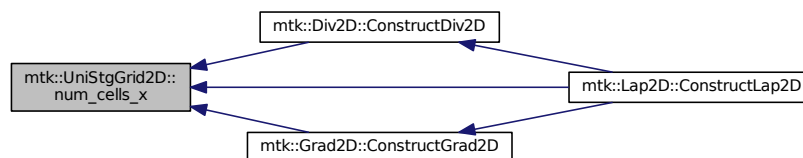
16.19.3.13 `int mtk::UniStgGrid2D::num_cells_x () const`

Returns

Number of cells of the grid.

Definition at line 220 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the caller graph for this function:



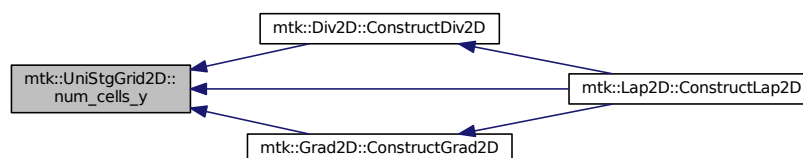
16.19.3.14 `int mtk::UniStgGrid2D::num_cells_y () const`

Returns

Number of cells of the grid.

Definition at line 245 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the caller graph for this function:



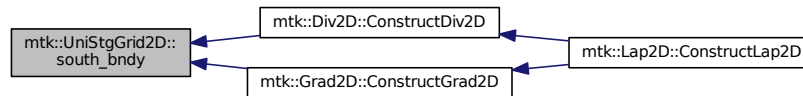
16.19.3.15 `mtk::Real mtk::UniStgGrid2D::south_bndy () const`

Returns

South boundary spatial coordinate.

Definition at line 235 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the caller graph for this function:



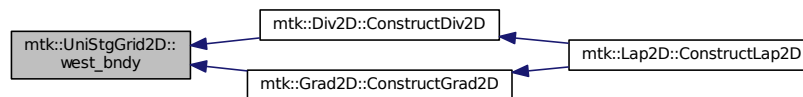
16.19.3.16 `mtk::Real mtk::UniStgGrid2D::west_bndy () const`

Returns

West boundary spatial coordinate.

Definition at line 210 of file [mtk_uni_stg_grid_2d.cc](#).

Here is the caller graph for this function:



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

Parameters

in	<i>filename</i>	Name of the output file.
in	<i>space_name_x</i>	Name for the first column of the (spatial) data.
in	<i>space_name_y</i>	Name for the second column of the (spatial) data.
in	<i>field_name</i>	Name for the second column of the (physical field) data.

Returns

Success of the file writing process.

See also

<http://www.gnuplot.info/>

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

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

Definition at line 420 of file [mtk_uni_stg_grid_2d.cc](#).

16.19.4 Friends And Related Function Documentation

16.19.4.1 `std::ostream& operator<< (std::ostream & stream, mtk::UniStgGrid2D & in)` [friend]

1. Print spatial coordinates.

2. Print scalar field.

Definition at line 67 of file [mtk_uni_stg_grid_2d.cc](#).

16.19.5 Member Data Documentation

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

Definition at line 290 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 295 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 281 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 282 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 283 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 288 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 285 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 293 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 289 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 294 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 292 of file [mtk_uni_stg_grid_2d.h](#).

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

Definition at line 287 of file [mtk_uni_stg_grid_2d.h](#).

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

- [include/mtk_uni_stg_grid_2d.h](#)
- [src/mtk_uni_stg_grid_2d.cc](#)

Chapter 17

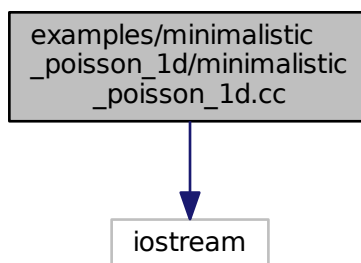
File Documentation

17.1 examples/minimalistic_poisson_1d/minimalistic_poisson_1d.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

```
#include <iostream>
```

Include dependency graph for minimalistic_poisson_1d.cc:



Functions

- int `main` ()

17.1.1 Detailed Description

We solve:

$$\nabla^2 p(x) = -s(x),$$

for $x \in \Omega = [a, b] = [0, 1]$.

The source term function is defined as

$$s(x) = \frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1}$$

where $\lambda = -1$ is a parameter.

We consider Robin's boundary conditions of the form:

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

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

The analytical solution for this problem is given by

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

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: Raul Vargas-Navarro - vargasna at rohan dot sdsu dot edu

Definition in file [minimalistic_poisson_1d.cc](#).

17.1.2 Function Documentation

17.1.2.1 int main ()

Definition at line 167 of file [minimalistic_poisson_1d.cc](#).

17.2 minimalistic_poisson_1d.cc

```

00001
00042 /*
00043 Copyright (C) 2015, Computational Science Research Center, San Diego State
00044 University. All rights reserved.
00045
00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
00048
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00050 and a copy of the modified files should be reported once modifications are
00051 completed, unless these modifications are made through the project's GitHub
00052 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00053 should be developed and included in any deliverable.
00054
00055 2. Redistributions of source code must be done through direct
00056 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00062 4. Usage of the binary form on proprietary applications shall require explicit
00063 prior written permission from the the copyright holders, and due credit should
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00079 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00080 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
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00082 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00083 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00084 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00085 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00086 */
00087
00088 #if __cplusplus == 201103L
00089
00090 #include <iostream>
00091 #include <fstream>
00092 #include <cmath>
00093 #include <vector>
00094
00095 #include "mtk.h"
00096
00097 mtk::Real Source(mtk::Real xx) {
00098     mtk::Real lambda = -1.0;
00099     return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00100 }
00101
00102 mtk::Real KnownSolution(mtk::Real xx) {
00103     mtk::Real lambda = -1.0;
00104     return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00105 }
00106
00107 int main () {
00108
00109     mtk::Real west_bndy_x = 0.0;
00110     mtk::Real east_bndy_x = 1.0;
00111     mtk::Real relative_norm_2_error{};
00112     int num_cells_x = 5;
00113     mtk::Grad1D grad;
00114     mtk::Lap1D lap;
00115     std::vector<mtk::Real> west_coeffs;
00116     std::vector<mtk::Real> east_coeffs;
00117     mtk::UniStgGrid1D source(west_bndy_x, east_bndy_x, num_cells_x);
00118     mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00119     mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00120
00121     if (!lap.ConstructLap1D()) {
00122         std::cerr << "Mimetic lap could not be built." << std::endl;
00123         return EXIT_FAILURE;
00124     }
00125     mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));
00126     if (!grad.ConstructGrad1D()) {
00127         std::cerr << "Mimetic grad could not be built." << std::endl;
00128         return EXIT_FAILURE;
00129     }
00130     mtk::DenseMatrix gradm(grad.ReturnAsDenseMatrix(comp_sol));
00131
00132     source.BindScalarField(Source);
00133
00134     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00135         west_coeffs.push_back(-(exp(-1.0) - 1.0)/-1.0)*gradm.GetValue(0, ii));
00136     }
00137     for (auto ii = 0; ii < grad.num_bndy_coeffs(); ++ii) {
00138         east_coeffs.push_back(
00139             (exp(-1.0) - 1.0)/-1.0)*gradm.GetValue(gradm.num_rows() - 1,
00140             gradm.num_cols() - 1 - ii);
00141     }
00142     west_coeffs[0] += -exp(-1.0);
00143     east_coeffs[0] += -exp(-1.0);
00144     mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(lapm,
00145         west_coeffs, east_coeffs);

```

```

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

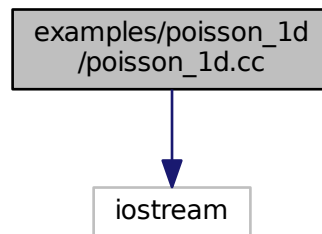
```

17.3 examples/poisson_1d/poisson_1d.cc File Reference

Poisson Equation on a 1D Uniform Staggered Grid with Robin BCs.

```
#include <iostream>
```

Include dependency graph for poisson_1d.cc:



Functions

- int `main` ()

17.3.1 Detailed Description

We solve:

$$\nabla^2 p(x) = -s(x),$$

for $x \in \Omega = [a, b] = [0, 1]$.

The source term function is defined as

$$s(x) = \frac{\lambda^2 \exp(\lambda x)}{\exp(\lambda) - 1}$$

where $\lambda = -1$ is a parameter.

We consider Robin's boundary conditions of the form:

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

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

The analytical solution for this problem is given by

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

Author

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 : Raul Vargas-Navarro - vargasna at rohan dot sdsu dot edu

Definition in file [poisson_1d.cc](#).

17.3.2 Function Documentation

17.3.2.1 int main ()

Definition at line 261 of file [poisson_1d.cc](#).

17.4 poisson_1d.cc

```
00001
00042 /*
00043 Copyright (C) 2015, Computational Science Research Center, San Diego State
00044 University. All rights reserved.
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00046 Redistribution and use in source and binary forms, with or without modification,
00047 are permitted provided that the following conditions are met:
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00049 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00050 and a copy of the modified files should be reported once modifications are
00051 completed, unless these modifications are made through the project's GitHub
00052 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00053 should be developed and included in any deliverable.
00054
00055 2. Redistributions of source code must be done through direct
00056 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00057
00058 3. Redistributions in binary form must reproduce the above copyright notice,
00059 this list of conditions and the following disclaimer in the documentation and/or
00060 other materials provided with the distribution.
00061
00062 4. Usage of the binary form on proprietary applications shall require explicit
```

```

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00072 third parties. The copyright holders disclaim any liability to any recipient for
00073 claims brought against recipient by any third party for infringement of that
00074 parties intellectual property rights.
00075
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00078 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00079 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00080 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00081 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00082 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00083 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00084 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00085 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00086 */
00087
00088 #if __cplusplus == 201103L
00089
00090 #include <iostream>
00091 #include <fstream>
00092 #include <cmath>
00093
00094 #include <vector>
00095
00096 #include "mtk.h"
00097
00098 mtk::Real Source(mtk::Real xx) {
00099
00100     mtk::Real lambda = -1.0;
00101
00102     return lambda*lambda*exp(lambda*xx)/(exp(lambda) - 1.0);
00103 }
00104
00105 mtk::Real KnownSolution(mtk::Real xx) {
00106
00107     mtk::Real lambda = -1.0;
00108
00109     return (exp(lambda*xx) - 1.0)/(exp(lambda) - 1.0);
00110 }
00111
00112 int main () {
00113
00114     std::cout << "Example: Poisson Equation on a 1D Uniform Staggered Grid ";
00115     std::cout << "with Robin BCs." << std::endl;
00116
00117     mtk::Real lambda = -1.0;
00118     mtk::Real alpha = -exp(lambda);
00119     mtk::Real beta = (exp(lambda) - 1.0)/lambda;
00120     mtk::Real omega = -1.0;
00121     mtk::Real epsilon = 0.0;
00122
00123     mtk::Real west_bndy_x = 0.0;
00124     mtk::Real east_bndy_x = 1.0;
00125     int num_cells_x = 5;
00126
00127     mtk::UniStgGrid1D comp_sol(west_bndy_x, east_bndy_x, num_cells_x);
00128
00129     int order_of_accuracy{2}; // Desired order of accuracy for approximation.
00130
00131     mtk::Grad1D grad; // Mimetic gradient operator.
00132
00133     mtk::Lapl1D lap; // Mimetic Laplacian operator.
00134
00135     if (!lap.ConstructLapl1D(order_of_accuracy)) {
00136         std::cerr << "Mimetic lap could not be built." << std::endl;
00137         return EXIT_FAILURE;
00138     }
00139
00140     mtk::DenseMatrix lapm(lap.ReturnAsDenseMatrix(comp_sol));

```



```

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

```

```

00230     std::cout << "Computed solution:" << std::endl;
00231     std::cout << source << std::endl;
00232
00233     source.WriteToFile("poisson_1d_comp_sol.dat", "x", "~u(x)");
00234
00235
00236
00237     mtk::UniStgGrid1D known_sol(west_bndy_x, east_bndy_x, num_cells_x);
00238
00239     known_sol.BindScalarField(KnownSolution);
00240
00241     std::cout << "known_sol =" << std::endl;
00242     std::cout << known_sol << std::endl;
00243
00244     known_sol.WriteToFile("poisson_1d_known_sol.dat", "x", "u(x)");
00245
00246     mtk::Real relative_norm_2_error{}; // Relative norm 2 of the error.
00247
00248     relative_norm_2_error =
00249         mtk::BLASAdapter::RelNorm2Error(source.discrete_field_u(),
00250                                         known_sol.discrete_field_u(),
00251                                         known_sol.num_cells_x());
00252
00253     std::cout << "relative_norm_2_error = ";
00254     std::cout << relative_norm_2_error << std::endl;
00255 }
00256
00257 #else
00258 #include <iostream>
00259 using std::cout;
00260 using std::endl;
00261 int main () {
00262     cout << "This code HAS to be compiled with support for C++11." << endl;
00263     cout << "Exiting..." << endl;
00264     return EXIT_SUCCESS;
00265 }
00266 #endif

```

17.5 include/mtk.h File Reference

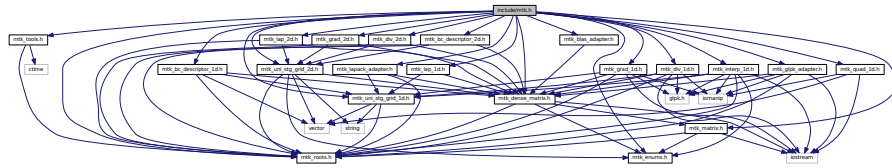
Includes the entire API.

```

#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_tools.h"
#include "mtk_matrix.h"
#include "mtk_dense_matrix.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_uni_stg_grid_1d.h"
#include "mtk_uni_stg_grid_2d.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
#include "mtk_bc_descriptor_1d.h"
#include "mtk_quad_1d.h"
#include "mtk_interp_1d.h"
#include "mtk_grad_2d.h"
#include "mtk_div_2d.h"
#include "mtk_lap_2d.h"
#include "mtk_bc_descriptor_2d.h"

```

Include dependency graph for mtk.h:



17.5.1 Detailed Description

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

Warning

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

Author

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

Definition in file [mtk.h](#).

17.6 mtk.h

```

00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
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00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00030
00031 3. Redistributions in binary form must reproduce the above copyright notice,
00032 this list of conditions and the following disclaimer in the documentation and/or
00033 other materials provided with the distribution.
00034
00035 4. Usage of the binary form on proprietary applications shall require explicit
00036 prior written permission from the the copyright holders, and due credit should
00037 be given to the copyright holders.
00038
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00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048

```

```

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00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00379 #ifndef MTK_INCLUDE_MTK_H_
00380 #define MTK_INCLUDE_MTK_H_
00381
00389 #include "mtk_roots.h"
00390
00398 #include "mtk_enums.h"
00399
00407 #include "mtk_tools.h"
00408
00416 #include "mtk_matrix.h"
00417 #include "mtk_dense_matrix.h"
00418
00426 #include "mtk_blas_adapter.h"
00427 #include "mtk_lapack_adapter.h"
00428 #include "mtk_glpk_adapter.h"
00429
00437 #include "mtk_uni_stg_grid_1d.h"
00438 #include "mtk_uni_stg_grid_2d.h"
00439
00447 #include "mtk_grad_1d.h"
00448 #include "mtk_div_1d.h"
00449 #include "mtk_lap_1d.h"
00450 #include "mtk_bc_descriptor_1d.h"
00451 #include "mtk_quad_1d.h"
00452 #include "mtk_interp_1d.h"
00453
00454 #include "mtk_grad_2d.h"
00455 #include "mtk_div_2d.h"
00456 #include "mtk_lap_2d.h"
00457 #include "mtk_bc_descriptor_2d.h"
00458
00459 #endif // End of: MTK_INCLUDE_MTK_H_

```

17.7 include/mtk_bc_descriptor_1d.h File Reference

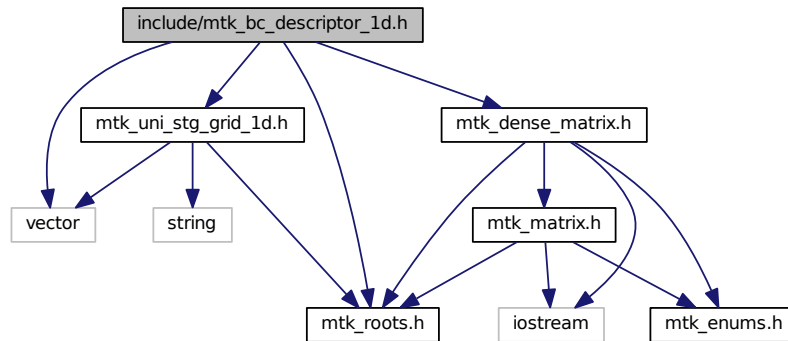
Enforces boundary conditions in either the operator or the grid.

```

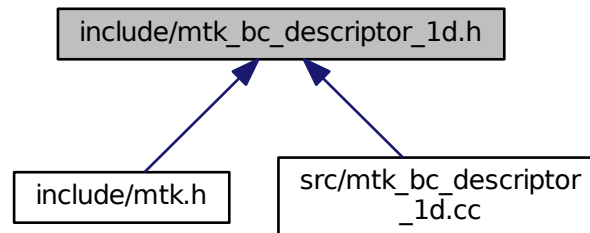
#include <vector>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_bc_descriptor_1d.h:



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



Classes

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

Namespaces

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

17.7.1 Detailed Description

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

Author

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

Definition in file [mtk_bc_descriptor_1d.h](#).

17.8 mtk_bc_descriptor_1d.h

```

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00011 /*
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00013 University. All rights reserved.
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
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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.
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <vector>
00058
00059 #include "mtk_roots.h"
00060 #include "mtk_dense_matrix.h"
00061 #include "mtk_uni_stg_grid_1d.h"
00062
00063 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
00064 #define MTK_INCLUDE_BC_DESCRIPTOR_1D_H_
00065
00066 namespace mtk {
00067
00068 class BCDescriptor1D {
00069 public:
00070     static void ImposeOnLaplacianMatrix(DenseMatrix &matrix,
00071                                         const std::vector<Real> &west,
00072                                         const std::vector<Real> &east);
00073
00074     static void ImposeOnGrid(UniStgGrid1D &grid,
00075                             const Real &epsilon,
00076                             const Real &omega);
00077 };
00078
00079
00080
00081
00082
00083
00084
00085
00086
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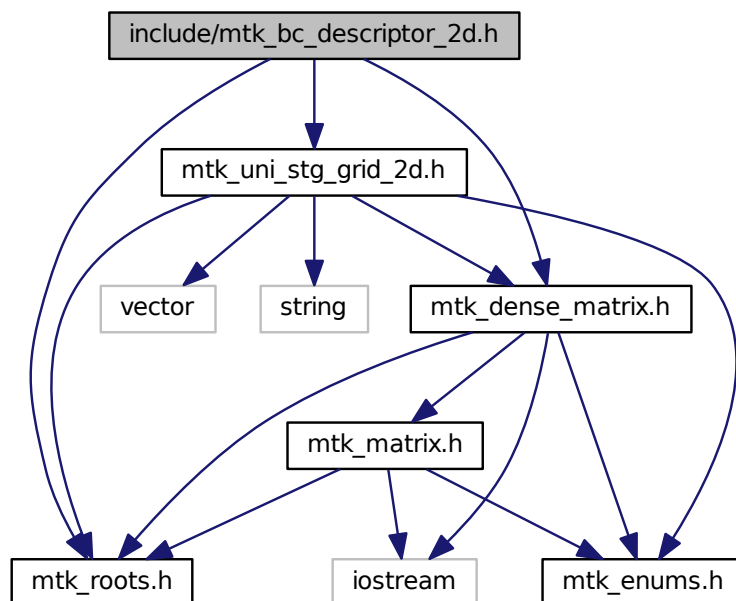
```

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

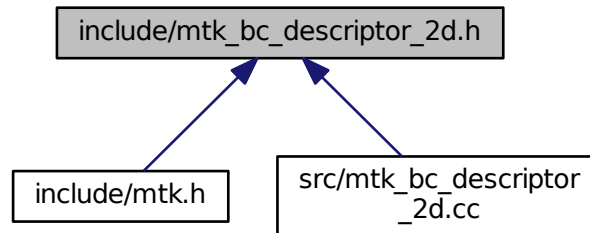
17.9 include/mtk_bc_descriptor_2d.h File Reference

Imposes boundary conditions in either the operator or the grid.

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



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



Classes

- class [mtk::BCDescriptor2D](#)

Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Typedefs

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

17.9.1 Detailed Description

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

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

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

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

Author

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

Definition in file [mtk_bc_descriptor_2d.h](#).

17.10 mtk_bc_descriptor_2d.h

```

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00038 completed, unless these modifications are made through the project's GitHub
00039 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00040 should be developed and included in any deliverable.
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00070 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00071 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00072 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00073 */
00074
00075 #ifndef MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00076 #define MTK_INCLUDE_BC_DESCRIPTOR_2D_H_
00077
00078 #include "mtk_roots.h"
00079 #include "mtk_dense_matrix.h"
00080 #include "mtk_uni_stg_grid_2d.h"
00081
00082 namespace mtk{
00083
00091 typedef Real (*CoefficientFunction2D)(Real, Real);
00092
00093 class BCDescriptor2D {
00094 public:
00096   BCDescriptor2D();
00097
00099   ~BCDescriptor2D();
00100
00106   BCDescriptor2D(const BCDescriptor2D &desc);
00107
00113   void PushBackWestCoeff(CoefficientFunction2D cw);
00114
00120   void PushBackEastCoeff(CoefficientFunction2D ce);
00121
00127   void PushBackSouthCoeff(CoefficientFunction2D cs);
00128
00134   void PushBackNorthCoeff(CoefficientFunction2D cn);
00135
00141   void set_west_condition_(mtk::Real (*
west_condition_)(Real xx, Real yy));
00142
00148   void set_east_condition_(mtk::Real (*

```

```

    east_condition_)(Real xx, Real yy));
00149
00155 void set_south_condition_(mtk::Real (*
south_condition_)(Real xx, Real yy));
00156
00162 void set_north_condition_(mtk::Real (*
north_condition_)(Real xx, Real yy));
00163
00170 void ImposeOnLaplacianMatrix(const UniStgGrid2D &grid,
00171                               DenseMatrix &matrix) const;
00172
00178 void ImposeOnGrid(UniStgGrid2D &grid) const;
00179
00180 private:
00181 int highest_order_differentiation_;
00182
00183 std::vector<CoefficientFunction2D> west_coefficients_;
00184 std::vector<CoefficientFunction2D> east_coefficients_;
00185 std::vector<CoefficientFunction2D> south_coefficients_;
00186 std::vector<CoefficientFunction2D> north_coefficients_;
00187
00188 mtk::Real (*west_condition_)(Real xx, Real yy);
00189 mtk::Real (*east_condition_)(Real xx, Real yy);
00190 mtk::Real (*south_condition_)(Real xx, Real yy);
00191 mtk::Real (*north_condition_)(Real xx, Real yy);
00192 };
00193 }
00194 #endif // End of: MTK_INCLUDE_BC_DESCRIPTOR_2D_H_

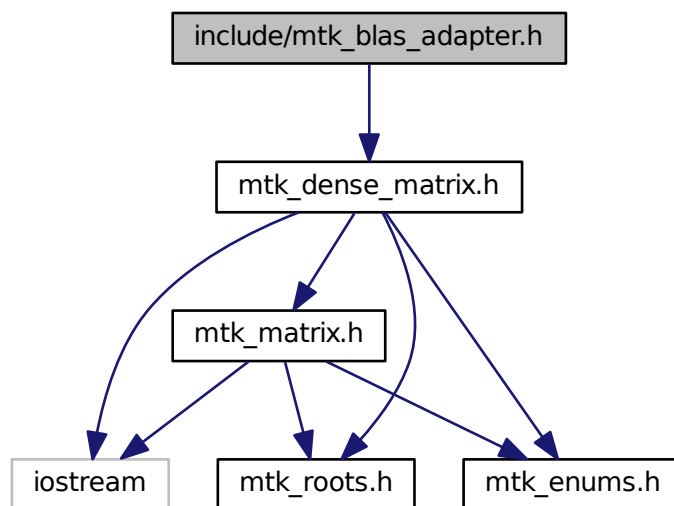
```

17.11 include/mtk_blas_adapter.h File Reference

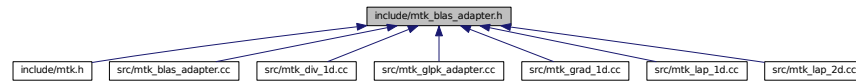
Adapter class for the BLAS API.

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

Include dependency graph for mtk_blas_adapter.h:



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



Classes

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

Namespaces

- `mtk`
Mimetic Methods Toolkit namespace.

17.11.1 Detailed Description

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

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

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

See also

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

Author

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

Definition in file [mtk_blas_adapter.h](#).

17.12 mtk_blas_adapter.h

```

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00024 /*
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00026 University. All rights reserved.
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00029 are permitted provided that the following conditions are met:
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00031 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00032 and a copy of the modified files should be reported once modifications are
00033 completed, unless these modifications are made through the project's GitHub
  
```

```

00034 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00035 should be developed and included in any deliverable.
00036
00037 2. Redistributions of source code must be done through direct
00038 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00039
00040 3. Redistributions in binary form must reproduce the above copyright notice,
00041 this list of conditions and the following disclaimer in the documentation and/or
00042 other materials provided with the distribution.
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00060 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00071 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00072
00073 #include "mtk_dense_matrix.h"
00074
00075 namespace mtk {
00076
00096 class BLASAdapter {
00097 public:
00106     static Real RealNRM2(Real *in, int &in_length);
00107
00124     static void RealAXPY(Real alpha, Real *xx, Real *yy, int &in_length);
00125
00140     static Real RelNorm2Error(Real *computed, Real *known, int length);
00141
00159     static void RealDenseMV(Real &alpha,
00160                             DenseMatrix &aa,
00161                             Real *xx,
00162                             Real &beta,
00163                             Real *yy);
00164
00179     static DenseMatrix RealDenseMM(DenseMatrix &aa,
00180                                    DenseMatrix &bb);
00181 };
00182 #endif // End of: MTK_INCLUDE_BLAS_ADAPTER_H_

```

17.13 include/mtk_dense_matrix.h File Reference

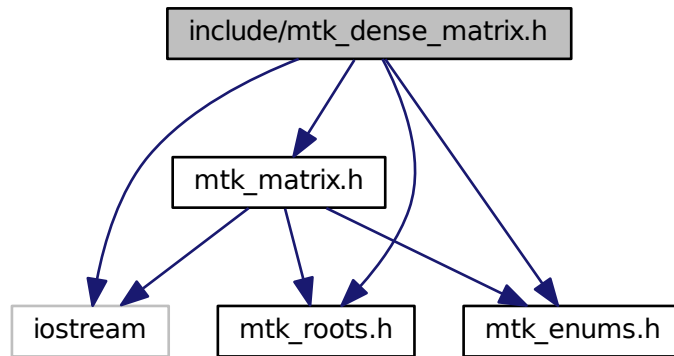
Defines a common dense matrix, using a 1D array.

```

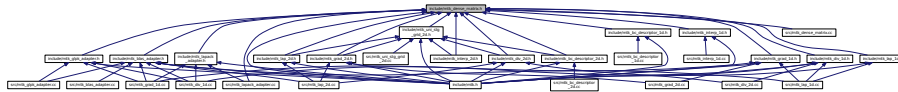
#include <iostream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_matrix.h"

```

Include dependency graph for mtk_dense_matrix.h:



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



Classes

- class [mtk::DenseMatrix](#)
Defines a common dense matrix, using a 1D array.

Namespaces

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

17.13.1 Detailed Description

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

Author

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

Note

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

Definition in file [mtk_dense_matrix.h](#).

17.14 mtk_dense_matrix.h

```

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00023 /*
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00025 University. All rights reserved.
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00028 are permitted provided that the following conditions are met:
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00030 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00031 and a copy of the modified files should be reported once modifications are
00032 completed, unless these modifications are made through the project's GitHub
00033 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00034 should be developed and included in any deliverable.
00035
00036 2. Redistributions of source code must be done through direct
00037 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00040 this list of conditions and the following disclaimer in the documentation and/or
00041 other materials provided with the distribution.
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00045 be given to the copyright holders.
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00049 specific prior written permission.
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00059 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00064 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00065 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00066 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00067 */
00068
00069 #ifndef MTK_INCLUDE_DENSE_MATRIX_H_
00070 #define MTK_INCLUDE_DENSE_MATRIX_H_
00071
00072 #include <iostream>
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_enums.h"
00076 #include "mtk_matrix.h"
00077
00078 namespace mtk {
00079
00092 class DenseMatrix {
00093 public:

```

```

00095     friend std::ostream& operator <<(std::ostream &stream, DenseMatrix &in);
00096
00098     DenseMatrix& operator =(const DenseMatrix &in);
00099
00101     bool operator ==(const DenseMatrix &in);
00102
00104     DenseMatrix();
00105
00111     DenseMatrix(const DenseMatrix &in);
00112
00121     DenseMatrix(const int &num_rows, const int &num_cols);
00122
00148     DenseMatrix(const int &rank, const bool &padded, const bool &transpose);
00149
00183     DenseMatrix(const Real *gen,
00184                 const int &gen_length,
00185                 const int &pro_length,
00186                 const bool &transpose);
00187
00189     ~DenseMatrix();
00190
00196     Matrix matrix_properties() const;
00197
00203     int num_rows() const;
00204
00210     int num_cols() const;
00211
00219     Real* data() const;
00220
00228     void SetOrdering(mtk::MatrixOrdering oo);
00229
00238     Real GetValue(const int &row_coord, const int &col_coord) const;
00239
00247     void SetValue(const int &row_coord,
00248                  const int &col_coord,
00249                  const Real &val);
00250
00252     void Transpose();
00253
00255     void OrderRowMajor();
00256
00258     void OrderColMajor();
00259
00270     static DenseMatrix Kron(const DenseMatrix &aa, const
DenseMatrix &bb);
00271
00281     bool WriteToFile(std::string filename) const;
00282
00283 private:
00284     Matrix matrix_properties_;
00285
00286     Real *data_;
00287 };
00288 }
00289 #endif // End of: MTK_INCLUDE_MTK_DENSE_MATRIX_H_

```

17.15 include/mtk_div_1d.h File Reference

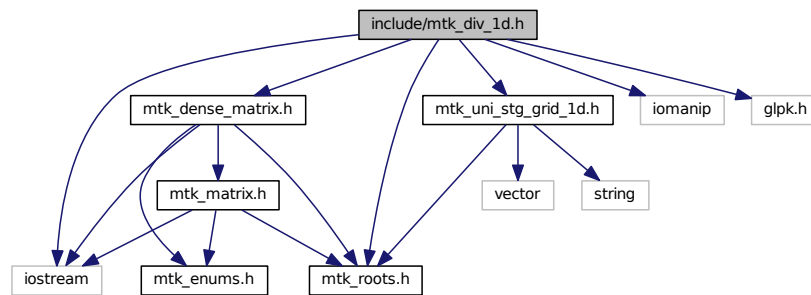
Includes the definition of the class Div1D.

```

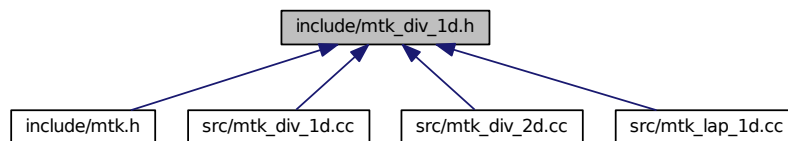
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for `mtk_div_1d.h`:



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



Classes

- class [mtk::Div1D](#)
Implements a 1D mimetic divergence operator.

Namespaces

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

17.15.1 Detailed Description

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

Author

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

Definition in file [mtk_div_1d.h](#).

17.16 mtk_div_1d.h

```

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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Div1D {
00082 public:
00083     friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00084
00085     Div1D();
00086
00087     Div1D(const Div1D &div);
00088
00089     ~Div1D();
00090
00091     bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00092                        Real mimetic_threshold = kDefaultMimeticThreshold);
00093
00094     int num_bndy_coeffs() const;
00095
00096     Real *coeffs_interior() const;
00097
00098
00099
00100
00101
00102
00103
00104
00105
00106
00107
00108
00109
00110
00111
00112
00113
00114
00115
00116
00117
00118
00119
00120

```

```

00126 Real *weights_crs(void) const;
00127
00133 Real *weights_cbs(void) const;
00134
00140 DenseMatrix mim_bndy() const;
00141
00147 DenseMatrix ReturnAsDenseMatrix(const
UniStgGrid1D &grid) const;
00148
00149 private:
00155 bool ComputeStencilInteriorGrid(void);
00156
00163 bool ComputeRationalBasisNullSpace(void);
00164
00170 bool ComputePreliminaryApproximations(void);
00171
00177 bool ComputeWeights(void);
00178
00184 bool ComputeStencilBoundaryGrid(void);
00185
00191 bool AssembleOperator(void);
00192
00193 int order_accuracy_;
00194 int dim_null_;
00195 int num_bndy_coeffs_;
00196 int divergence_length_;
00197 int minrow_;
00198 int row_;
00199
00200 DenseMatrix rat_basis_null_space_;
00201
00202 Real *coeffs_interior_;
00203 Real *prem_apps_;
00204 Real *weights_crs_;
00205 Real *weights_cbs_;
00206 Real *mim_bndy_;
00207 Real *divergence_;
00208
00209 Real mimetic_threshold_;
00210 };
00211 }
00212 #endif // End of: MTK_INCLUDE_DIV_1D_H_

```

17.17 include/mtk_div_2d.h File Reference

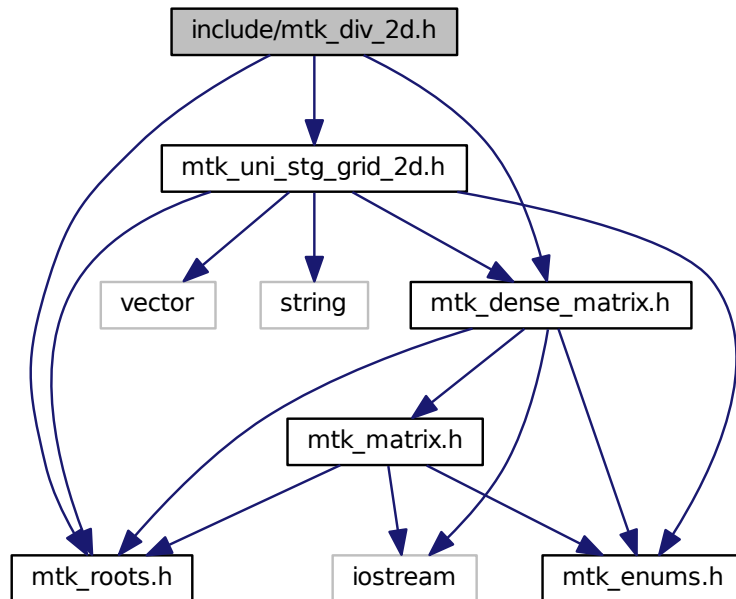
Includes the definition of the class Div2D.

```

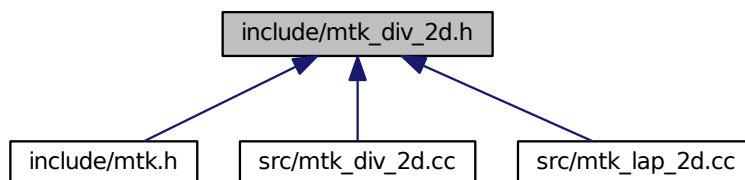
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"

```

Include dependency graph for mtk_div_2d.h:



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



Classes

- class [mtk::Div2D](#)

Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

17.17.1 Detailed Description

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

Author

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

Definition in file [mtk_div_2d.h](#).

17.18 mtk_div_2d.h

```

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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_DIV_2D_H_
00058 #define MTK_INCLUDE_MTK_DIV_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class Div2D {
00067 public:
00068     Div2D();
00069
00070

```

```

00076   Div2D(const Div2D &div);
00077
00079   ~Div2D();
00080
00086   bool ConstructDiv2D(const UniStgGrid2D &grid,
00087                     int order_accuracy = kDefaultOrderAccuracy,
00088                     Real mimetic_threshold = kDefaultMimeticThreshold);
00089
00095   DenseMatrix ReturnAsDenseMatrix() const;
00096
00097 private:
00098   DenseMatrix divergence_;
00099
00100   int order_accuracy_;
00101
00102   Real mimetic_threshold_;
00103 };
00104 }
00105 #endif // End of: MTK_INCLUDE_MTK_DIV_2D_H_

```

17.19 include/mtk_enums.h File Reference

Considered enumeration types in the MTK.

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



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Enumerations

- enum [mtk::MatrixStorage](#) { [mtk::DENSE](#), [mtk::BANDED](#), [mtk::CRS](#) }
Considered matrix storage schemes to implement sparse matrices.
- enum [mtk::MatrixOrdering](#) { [mtk::ROW_MAJOR](#), [mtk::COL_MAJOR](#) }
Considered matrix ordering (for Fortran purposes).
- enum [mtk::FieldNature](#) { [mtk::SCALAR](#), [mtk::VECTOR](#) }
Nature of the field discretized in a given grid.
- enum [mtk::DirInterp](#) { [mtk::SCALAR_TO_VECTOR](#), [mtk::VECTOR_TO_SCALAR](#) }
Interpolation operator.

17.19.1 Detailed Description

Enumeration types are used throughout the MTK to differentiate instances of derived classes, as well as for mnemonic purposes. In this file, the enumeration types are listed alphabetically.

Author

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

Definition in file [mtk_enums.h](#).

17.20 mtk_enums.h

```

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00012 /*
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00014 University. All rights reserved.
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00017 are permitted provided that the following conditions are met:
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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
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00025 2. Redistributions of source code must be done through direct
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_ENUMS_H_
00059 #define MTK_INCLUDE_ENUMS_H_
00060
00061 namespace mtk {
00062
00077 enum MatrixStorage {
00078     DENSE,
00079     BANDED,
00080     CRS
00081 };
00082
00095 enum MatrixOrdering {
00096     ROW_MAJOR,
00097     COL_MAJOR
00098 };
00099
00113 enum FieldNature {
00114     SCALAR,
00115     VECTOR
00116 };
00117

```

```

00127 enum DirInterp {
00128     SCALAR_TO_VECTOR,
00129     VECTOR_TO_SCALAR
00130 };
00131 }
00132 #endif // End of: MTK_INCLUDE_ENUMS_H_

```

17.21 include/mtk_glpk_adapter.h File Reference

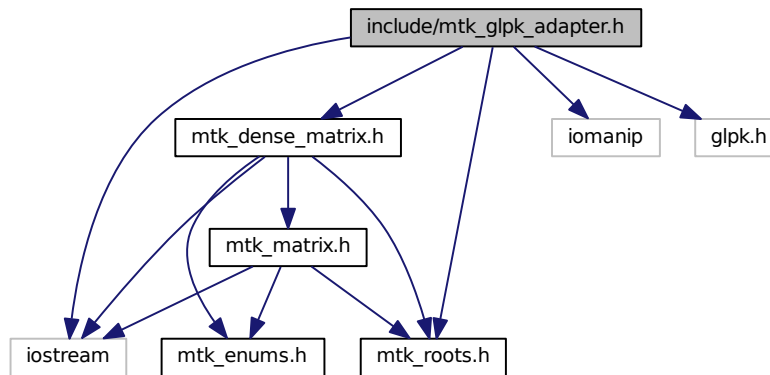
Adapter class for the GLPK API.

```

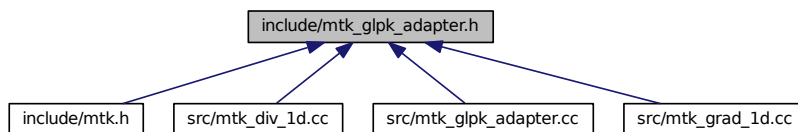
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"

```

Include dependency graph for mtk_glpk_adapter.h:



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



Classes

- class [mtk::GLPKAdapter](#)

Adapter class for the GLPK API.

Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

17.21.1 Detailed Description

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

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

See also

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

Author

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

Definition in file [mtk_glpk_adapter.h](#).

17.22 mtk_glpk_adapter.h

```

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00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
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00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00037 other materials provided with the distribution.
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00040 prior written permission from the the copyright holders, and due credit should
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00066 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00067
00068 #include <iostream>
00069 #include <iomanip>
00070
00071 #include "glpk.h"
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075
00076 namespace mtk {
00077
00101 class GLPKAdapter {
00102 public:
00123     static mtk::Real SolveSimplexAndCompare(
00124         mtk::Real *A,
00125         int nrow,
00126         int ncol,
00127         mtk::Real *hh,
00128         mtk::Real *qq,
00129         int robjective,
00130         mtk::Real mimetic_tol,
00131         int copy);
00132 };
00133 }
00134 #endif // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_

```

17.23 include/mtk_grad_1d.h File Reference

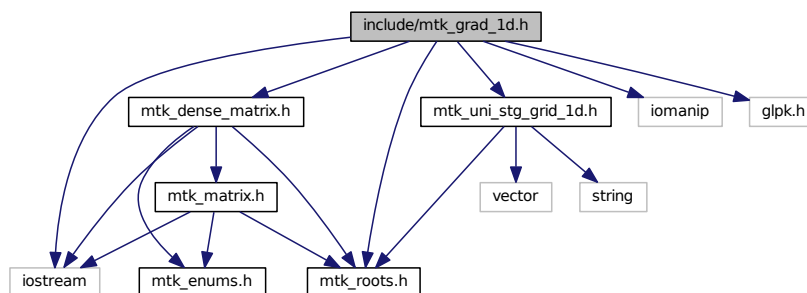
Includes the definition of the class Grad1D.

```

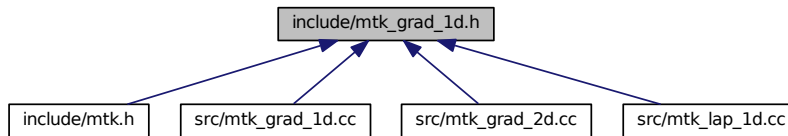
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_grad_1d.h:



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



Classes

- class [mtk::Grad1D](#)
Implements a 1D mimetic gradient operator.

Namespaces

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

17.23.1 Detailed Description

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

Author

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

Definition in file [mtk_grad_1d.h](#).

17.24 mtk_grad_1d.h

```

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00013 University. All rights reserved.
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030

```

```

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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_GRAD_1D_H_
00058 #define MTK_INCLUDE_GRAD_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
00070
00081 class Grad1D {
00082 public:
00083     friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00084
00085     Grad1D();
00086
00087     Grad1D(const Grad1D &grad);
00088
00089     ~Grad1D();
00090
00091     bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00092                         Real mimetic_threshold = kDefaultMimeticThreshold);
00093
00094     int num_bndy_coeffs() const;
00095
00096     Real *coeffs_interior() const;
00097
00098     Real *weights_crs(void) const;
00099
00100     Real *weights_cbs(void) const;
00101
00102     DenseMatrix mim_bndy() const;
00103
00104     DenseMatrix ReturnAsDenseMatrix(Real west,
00105                                     Real east, int num_cells_x) const;
00106
00107     DenseMatrix ReturnAsDenseMatrix(const
00108                                     UniStgGrid1D &grid) const;
00109
00110     DenseMatrix ReturnAsDimensionlessDenseMatrix(int num_cells_x)
00111     const;
00112
00113 private:
00114     bool ComputeStencilInteriorGrid(void);
00115
00116     bool ComputeRationalBasisNullSpace(void);
00117
00118     bool ComputePreliminaryApproximations(void);
00119
00120     bool ComputeWeights(void);
00121
00122

```

```

00198  bool ComputeStencilBoundaryGrid(void);
00199
00205  bool AssembleOperator(void);
00206
00207  int order_accuracy_;
00208  int dim_null_;
00209  int num_bndy_approxs_;
00210  int num_bndy_coeffs_;
00211  int gradient_length_;
00212  int minrow_;
00213  int row_;
00214
00215  DenseMatrix rat_basis_null_space_;
00216
00217  Real *coeffs_interior_;
00218  Real *prem_apps_;
00219  Real *weights_crs_;
00220  Real *weights_cbs_;
00221  Real *mim_bndy_;
00222  Real *gradient_;
00223
00224  Real mimetic_threshold_;
00225 };
00226 }
00227 #endif // End of: MTK_INCLUDE_GRAD_1D_H_

```

17.25 include/mtk_grad_2d.h File Reference

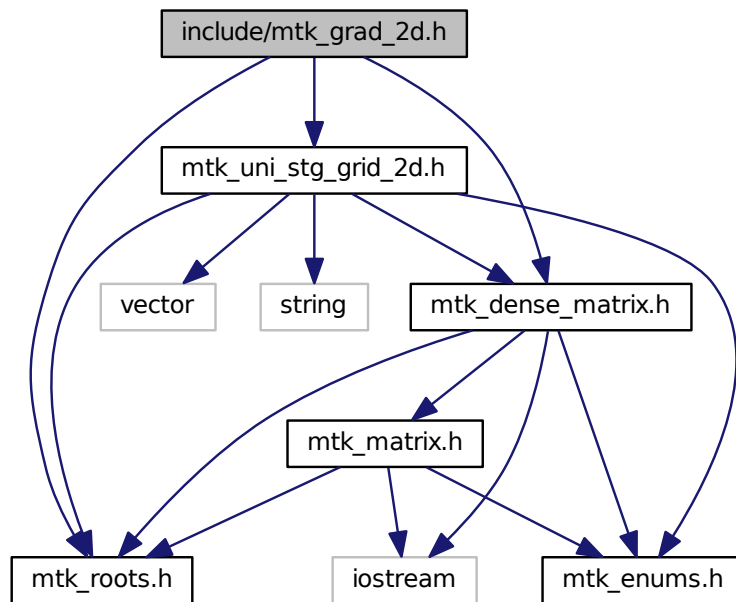
Includes the definition of the class Grad2D.

```

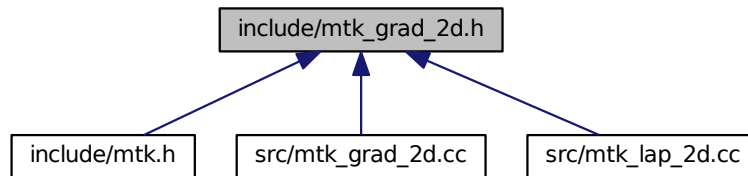
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"

```

Include dependency graph for mtk_grad_2d.h:



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



Classes

- class [mtk::Grad2D](#)

Namespaces

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

17.25.1 Detailed Description

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

Author

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

Definition in file [mtk_grad_2d.h](#).

17.26 mtk_grad_2d.h

```

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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
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```

```

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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_MTK_GRAD_2D_H_
00058 #define MTK_INCLUDE_MTK_GRAD_2D_H_
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_dense_matrix.h"
00062 #include "mtk_uni_stg_grid_2d.h"
00063
00064 namespace mtk{
00065
00066 class Grad2D {
00067 public:
00068     Grad2D();
00069
00070     Grad2D(const Grad2D &grad);
00071
00072     ~Grad2D();
00073
00074     bool ConstructGrad2D(const UniStgGrid2D &grid,
00075                         int order_accuracy = kDefaultOrderAccuracy,
00076                         Real mimetic_threshold = kDefaultMimeticThreshold);
00077
00078     DenseMatrix ReturnAsDenseMatrix() const;
00079
00080 private:
00081     DenseMatrix gradient_;
00082
00083     int order_accuracy_;
00084     Real mimetic_threshold_;
00085 };
00086
00087 #endif // End of: MTK_INCLUDE_MTK_GRAD_2D_H_

```

17.27 include/mtk_interp_1d.h File Reference

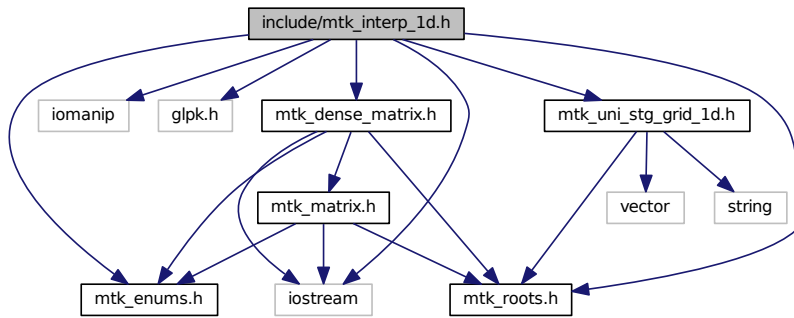
Includes the definition of the class Interp1D.

```

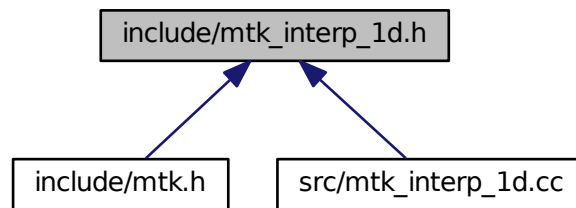
#include <iostream>
#include <iomanip>
#include "glpk.h"
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_interp_1d.h:



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



Classes

- class [mtk::Interp1D](#)
Implements a 1D interpolation operator.

Namespaces

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

17.27.1 Detailed Description

This class implements a 1D interpolation operator.

Author

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

Definition in file [mtk_interp_1d.h](#).

17.28 mtk_interp_1d.h

```

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00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
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00025 2. Redistributions of source code must be done through direct
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_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
00073 class Interp1D {
00074 public:
00075     friend std::ostream& operator <<(std::ostream& stream, Interp1D &in);
00076
00077 };
00078
00079 }
00080
00081 #endif
00082
00083
00084
00085
00086

```



```

00088   Interp1D();
00089
00095   Interp1D(const Interp1D &interp);
00096
00098   ~Interp1D();
00099
00105   bool ConstructInterp1D(int order_accuracy =
kDefaultOrderAccuracy,
00106                           mtk::DirInterp dir = SCALAR_TO_VECTOR);
00107
00113   Real *coeffs_interior() const;
00114
00120   DenseMatrix ReturnAsDenseMatrix(const
UniStgGrid1D &grid) const;
00121
00122   private:
00123   DirInterp dir_interp_;
00124
00125   int order_accuracy_;
00126
00127   Real *coeffs_interior_;
00128 };
00129 }
00130 #endif // End of: MTK_INCLUDE_INTERP_1D_H_

```

17.29 include/mtk_interp_2d.h File Reference

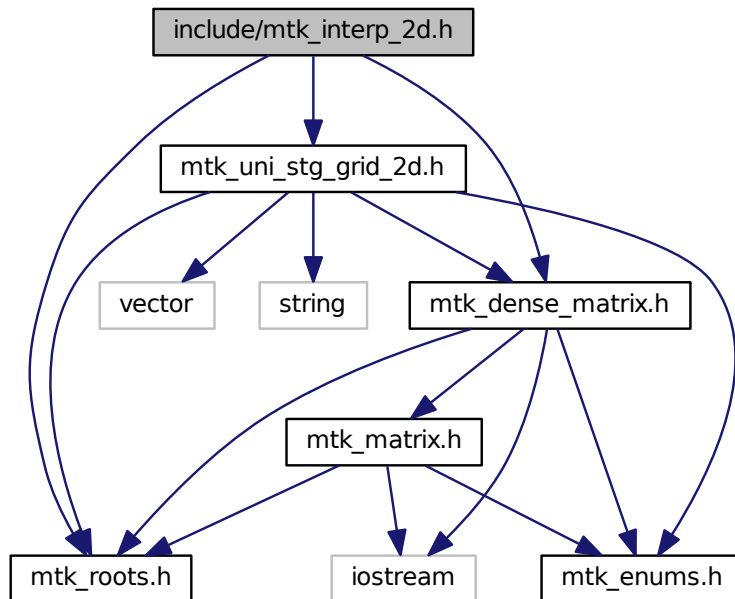
Includes the definition of the class Interp2D.

```

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

```

Include dependency graph for mtk_interp_2d.h:



Classes

- class [mtk::Interp2D](#)

Namespaces

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

17.29.1 Detailed Description

This class implements a 2D interpolation operator.

Author

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

Definition in file [mtk_interp_2d.h](#).

17.30 mtk_interp_2d.h

```

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00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
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00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00029 this list of conditions and the following disclaimer in the documentation and/or
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```

```

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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
00067 class Interp2D {
00068 public:
00070     Interp2D();
00071
00077     Interp2D(const Interp2D &interp);
00078
00080     ~Interp2D();
00081
00087     DenseMatrix ConstructInterp2D(const UniStgGrid2D &grid,
00088                                 int order_accuracy = kDefaultOrderAccuracy,
00089                                 Real mimetic_threshold =
00090                                 kDefaultMimeticThreshold);
00096     DenseMatrix ReturnAsDenseMatrix();
00097
00098 private:
00099     DenseMatrix interpolator_;
00100
00101     int order_accuracy_;
00102
00103     Real mimetic_threshold_;
00104 };
00105 }
00106 #endif // End of: MTK_INCLUDE_MTK_INTERP_2D_H_

```

17.31 include/mtk_lap_1d.h File Reference

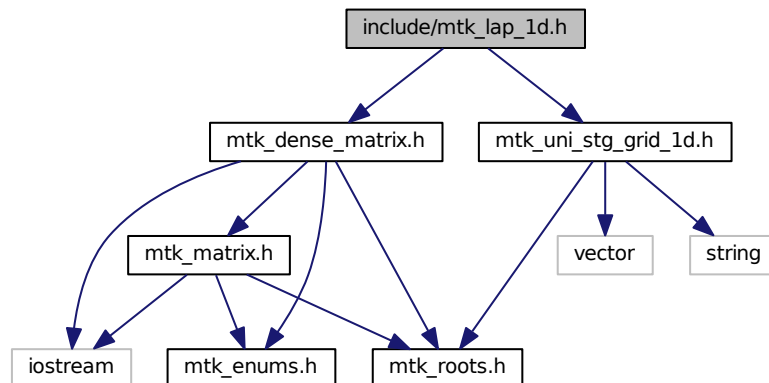
Includes the definition of the class Lap1D.

```

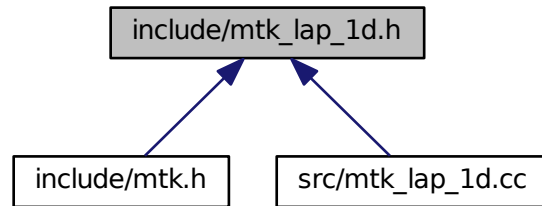
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_lap_1d.h:



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



Classes

- class `mtk::Lap1D`
Implements a 1D mimetic Laplacian operator.

Namespaces

- `mtk`
Mimetic Methods Toolkit namespace.

17.31.1 Detailed Description

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

Author

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

Definition in file `mtk_lap_1d.h`.

17.32 mtk_lap_1d.h

```

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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023

```

```

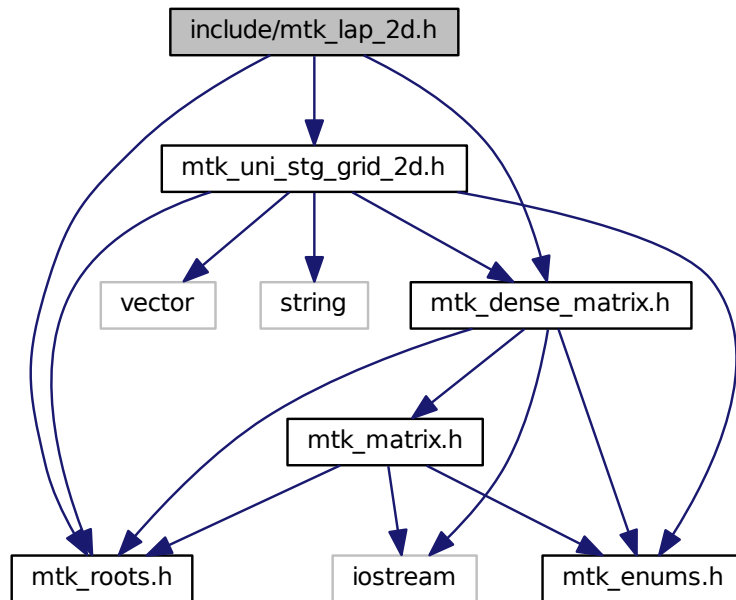
00024 2. Redistributions of source code must be done through direct
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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_LAP_1D_H_
00058 #define MTK_INCLUDE_LAP_1D_H_
00059
00060 #include "mtk_dense_matrix.h"
00061
00062 #include "mtk_uni_stg_grid_1d.h"
00063
00064 namespace mtk {
00065
00066 class Lap1D {
00067 public:
00068     friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00069
00070     Lap1D();
00071
00072     Lap1D(const Lap1D &lap);
00073
00074     ~Lap1D();
00075
00076     bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00077                        Real mimetic_threshold = kDefaultMimeticThreshold);
00078
00079     DenseMatrix ReturnAsDenseMatrix(const
00080 UniStgGrid1D &grid) const;
00081
00082     const mtk::Real* data(const UniStgGrid1D &grid) const;
00083
00084 private:
00085     int order_accuracy_;
00086     int laplacian_length_;
00087
00088     Real *laplacian_;
00089
00090     Real mimetic_threshold_;
00091 };
00092
00093 #endif // End of: MTK_INCLUDE_LAP_1D_H_

```

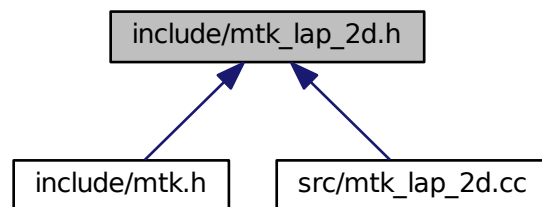
17.33 include/mtk_lap_2d.h File Reference

Includes the implementation of the class Lap2D.

```
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_2d.h"
Include dependency graph for mtk_lap_2d.h:
```



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



Classes

- class [mtk::Lap2D](#)

Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

17.33.1 Detailed Description

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

Author

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

Definition in file [mtk_lap_2d.h](#).

17.34 mtk_lap_2d.h

```

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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
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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.
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00047 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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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
00066 class Lap2D {
00067 public:
00068     Lap2D();
00070
00071     Lap2D(const Lap2D &lap);
00072
00073     ~Lap2D();
00074
00075     bool ConstructLap2D(const UniStgGrid2D &grid,
00076                        int order_accuracy = kDefaultOrderAccuracy,
00077                        Real mimetic_threshold = kDefaultMimeticThreshold);
00078
00079     DenseMatrix ReturnAsDenseMatrix() const;
00080
00081     Real *data() const;
00082
00083 private:
00084     DenseMatrix laplacian_;
00085
00086     int order_accuracy_;
00087     Real mimetic_threshold_;
00088 };
00089
00090 #endif // End of: MTK_INCLUDE_MTK_LAP_2D_H_

```

17.35 include/mtk_lapack_adapter.h File Reference

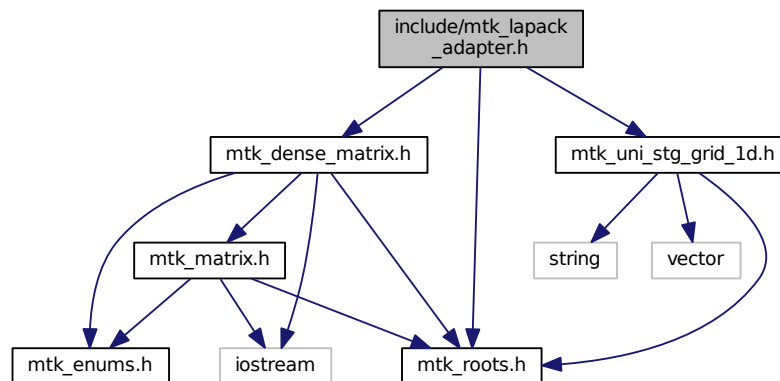
Adapter class for the LAPACK API.

```

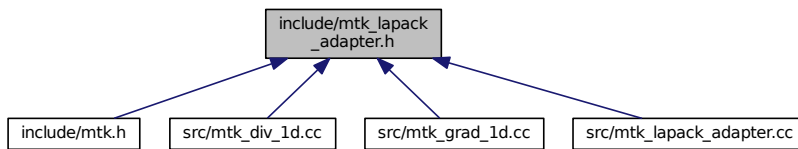
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_lapack_adapter.h:



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



Classes

- class [mtk::LAPACKAdapter](#)
Adapter class for the LAPACK API.

Namespaces

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

17.35.1 Detailed Description

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

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

See also

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

Author

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

Definition in file [mtk_lapack_adapter.h](#).

17.36 mtk_lapack_adapter.h

```

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00027 and a copy of the modified files should be reported once modifications are

```

```

00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.cs.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.cs.csrc.sdsu.edu/mtk
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00066 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00067
00068 #include "mtk_roots.h"
00069 #include "mtk_dense_matrix.h"
00070 #include "mtk_uni_stg_grid_ld.h"
00071
00072 namespace mtk {
00073
00092 class LAPACKAdapter {
00093 public:
00104     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00105                                mtk::Real *rhs);
00106
00117     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00118                                mtk::DenseMatrix &rr);
00119
00130     static int SolveDenseSystem(mtk::DenseMatrix &mm,
00131                                mtk::UniStgGridLD &rhs);
00132
00144     static int SolveRectangularDenseSystem(const
00145 mtk::DenseMatrix &aa,
00146                                           mtk::Real *ob_,
00147                                           int ob_ld_);
00148
00159     static mtk::DenseMatrix QRFactorDenseMatrix(
00160 DenseMatrix &matrix);
00161 };
00162 #endif // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_

```

17.37 include/mtk_matrix.h File Reference

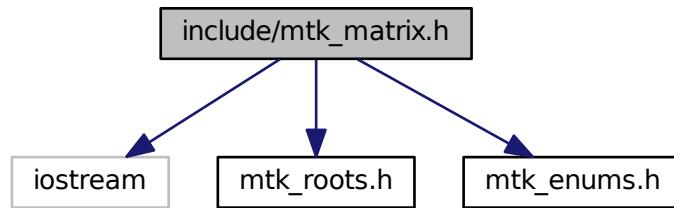
Definition of the representation of a matrix in the MTK.

```

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

```

Include dependency graph for mtk_matrix.h:



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



Classes

- class [mtk::Matrix](#)

Definition of the representation of a matrix in the MTK.

Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

17.37.1 Detailed Description

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

Author

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

Definition in file [mtk_matrix.h](#).

17.38 mtk_matrix.h

```

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00010 /*
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```

```

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00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00027 this list of conditions and the following disclaimer in the documentation and/or
00028 other materials provided with the distribution.
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00030 4. Usage of the binary form on proprietary applications shall require explicit
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00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
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00042 parties intellectual property rights.
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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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 #ifndef MTK_INCLUDE_MATRIX_H_
00057 #define MTK_INCLUDE_MATRIX_H_
00058
00059 #include <iostream>
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_enums.h"
00063
00064 namespace mtk {
00065
00075 class Matrix {
00076 public:
00077     Matrix();
00078
00079     Matrix(const Matrix &in);
00080
00081     ~Matrix();
00082
00083     MatrixStorage storage() const;
00084
00085     MatrixOrdering ordering() const;
00086
00087     int num_rows() const;
00088
00089     int num_cols() const;
00090
00091     int num_values() const;
00092
00093     int ld() const;
00094
00095     int num_zero() const;
00096
00097     int num_non_zero() const;
00098
00099     int num_null() const;
00100
00101     int num_non_null() const;

```

```

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

```

17.39 include/mtk_quad_1d.h File Reference

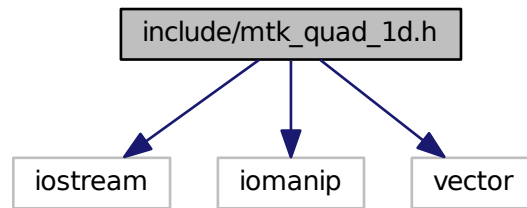
Includes the definition of the class Quad1D.

```

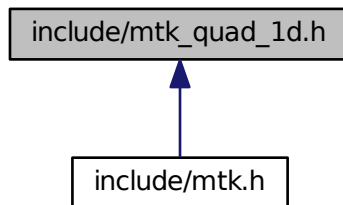
#include <iostream>
#include <iomanip>
#include <vector>

```

Include dependency graph for `mtk_quad_1d.h`:



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



Classes

- class [mtk::Quad1D](#)
Implements a 1D mimetic quadrature.

Namespaces

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

17.39.1 Detailed Description

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

See also

[mtk::Grad1D](#)

Author

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

Todo Implement this class.

Definition in file [mtk_quad_1d.h](#).

17.40 mtk_quad_1d.h

```

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00023 and a copy of the modified files should be reported once modifications are
00024 completed, unless these modifications are made through the project's GitHub
00025 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00026 should be developed and included in any deliverable.
00027
00028 2. Redistributions of source code must be done through direct
00029 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #ifndef MTK_INCLUDE_QUAD_1D_H_
00062 #define MTK_INCLUDE_QUAD_1D_H_
00063
00064 #include <iostream>
00065 #include <iomanip>
00066
00067 #include <vector>
00068
00069 namespace mtk {
00070
00081 class Quad1D {
00082 public:
00084     friend std::ostream& operator <<(std::ostream& stream, Quad1D &in);
00085
00087     Quad1D();
00088
00094     Quad1D(const Quad1D &quad);
00095

```

```

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

```

17.41 include/mtk_roots.h File Reference

Fundamental definitions to be used across all classes of the MTK.

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



Namespaces

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

Typedefs

- typedef float [mtk::Real](#)
Users can simply change this to build a double- or single-precision MTK.

Variables

- const float [mtk::kZero](#) {0.0f}
MTK's zero defined according to selective compilation.
- const float [mtk::kOne](#) {1.0f}
MTK's one defined according to selective compilation.
- const float [mtk::kDefaultTolerance](#) {1e-7f}
Considered tolerance for comparisons in numerical methods.
- const int [mtk::kDefaultOrderAccuracy](#) {2}
Default order of accuracy for mimetic operators.
- const float [mtk::kDefaultMimeticThreshold](#) {1e-6f}
Default tolerance for higher-order mimetic operators.
- const int [mtk::kCriticalOrderAccuracyDiv](#) {8}
At this order (and higher) we must use the CBSA to construct.
- const int [mtk::kCriticalOrderAccuracyGrad](#) {10}
At this order (and higher) we must use the CBSA to construct.

17.41.1 Detailed Description

This file contains the fundamental definitions that classes of the MTK rely on to be implemented. Examples of these definitions are the definition of fundamental data types, and global variables affecting the construction of mimetic operators, among others.

Author

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

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

Todo Test selective precision mechanisms.

Definition in file [mtk_roots.h](#).

17.42 mtk_roots.h

```

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00019 University. All rights reserved.
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00022 are permitted provided that the following conditions are met:
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00025 and a copy of the modified files should be reported once modifications are
00026 completed, unless these modifications are made through the project's GitHub
00027 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00028 should be developed and included in any deliverable.
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00030 2. Redistributions of source code must be done through direct
00031 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00033 3. Redistributions in binary form must reproduce the above copyright notice,
00034 this list of conditions and the following disclaimer in the documentation and/or
00035 other materials provided with the distribution.
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00037 4. Usage of the binary form on proprietary applications shall require explicit
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00047 third parties. The copyright holders disclaim any liability to any recipient for
00048 claims brought against recipient by any third party for infringement of that
00049 parties intellectual property rights.
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00053 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00058 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00059 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00060 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00061 */
00062
00063 #ifndef MTK_INCLUDE_ROOTS_H_
00064 #define MTK_INCLUDE_ROOTS_H_
00065
00071 namespace mtk {

```


Classes

- class [mtk::Tools](#)
Tool manager class.

Namespaces

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

17.43.1 Detailed Description

Basic utilities.

Author

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

Note

Performance Tip 8.1. If they do not need to be modified by the called function, pass large objects using pointers to constant data or references to constant data, to obtain the performance benefits of pass-by-reference.

Definition in file [mtk_tools.h](#).

17.44 mtk_tools.h

```
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00022 and a copy of the modified files should be reported once modifications are
00023 completed, unless these modifications are made through the project's GitHub
00024 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00025 should be developed and included in any deliverable.
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00027 2. Redistributions of source code must be done through direct
00028 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00029
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00032 other materials provided with the distribution.
00033
00034 4. Usage of the binary form on proprietary applications shall require explicit
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00046 parties intellectual property rights.
00047
```

```

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00055 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00056 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00057 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00058 */
00059
00060 #ifndef MTK_INCLUDE_TOOLS_H_
00061 #define MTK_INCLUDE_TOOLS_H_
00062
00063 #include <ctime>
00064
00065 #include "mtk_roots.h"
00066
00067 namespace mtk {
00068
00078 class Tools {
00079 public:
00090     static void Prevent(const bool complement,
00091                         const char *fname,
00092                         int lineno,
00093                         const char *fxname);
00094
00100     static void BeginUnitTestNo(const int &nn);
00101
00107     static void EndUnitTestNo(const int &nn);
00108
00114     static void Assert(const bool condition);
00115
00116 private:
00117     static int test_number_;
00118
00119     static Real duration_;
00120
00121     static clock_t begin_time_;
00122 };
00123 }
00124 #endif // End of: MTK_INCLUDE_TOOLS_H_

```

17.45 include/mtk_uni_stg_grid_1d.h File Reference

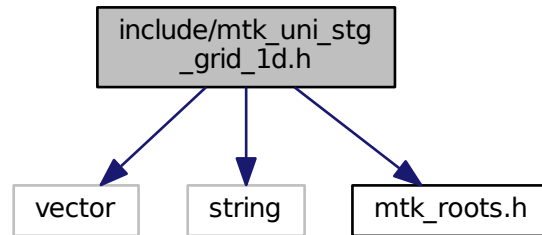
Definition of an 1D uniform staggered grid.

```

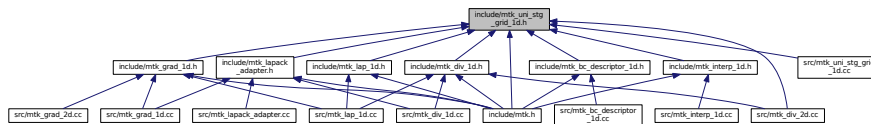
#include <vector>
#include <string>
#include "mtk_roots.h"

```

Include dependency graph for mtk_uni_stg_grid_1d.h:



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



Classes

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

Namespaces

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

17.45.1 Detailed Description

Definition of an 1D uniform staggered grid.

Author

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

Todo Create overloaded binding routines that read data from files.

Definition in file [mtk_uni_stg_grid_1d.h](#).

17.46 mtk_uni_stg_grid_1d.h

```

00001
00012 /*
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00014 University. All rights reserved.
00015
00016 Redistribution and use in source and binary forms, with or without modification,
00017 are permitted provided that the following conditions are met:
00018
00019 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00020 and a copy of the modified files should be reported once modifications are
00021 completed, unless these modifications are made through the project's GitHub
00022 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00023 should be developed and included in any deliverable.
00024
00025 2. Redistributions of source code must be done through direct
00026 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00027
00028 3. Redistributions in binary form must reproduce the above copyright notice,
00029 this list of conditions and the following disclaimer in the documentation and/or
00030 other materials provided with the distribution.
00031
00032 4. Usage of the binary form on proprietary applications shall require explicit
00033 prior written permission from the the copyright holders, and due credit should
00034 be given to the copyright holders.
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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
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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_1D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_1D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065
00066 namespace mtk {
00067
00077 class UniStgGrid1D {
00078 public:
00080     friend std::ostream& operator <<(std::ostream& stream, UniStgGrid1D &in);
00081
00083     UniStgGrid1D();
00084
00090     UniStgGrid1D(const UniStgGrid1D &grid);
00091
00102     UniStgGrid1D(const Real &west_bndy_x,
00103                  const Real &east_bndy_x,
00104                  const int &num_cells_x,
00105                  const mtk::FieldNature &nature = mtk::SCALAR);
00106
00108     ~UniStgGrid1D();
00109
00115     Real west_bndy_x() const;
00116
00122     Real east_bndy_x() const;
00123
00129     Real delta_x() const;
00130

```

```

00138  const Real *discrete_domain_x() const;
00139
00147  Real *discrete_field_u();
00148
00154  int num_cells_x() const;
00155
00161  void BindScalarField(Real (*ScalarField)(Real xx));
00162
00174  void BindVectorField(Real (*VectorField)(Real xx));
00175
00187  bool WriteToFile(std::string filename,
00188                  std::string space_name,
00189                  std::string field_name) const;
00190
00191 private:
00192  FieldNature nature_;
00193
00194  std::vector<Real> discrete_domain_x_;
00195  std::vector<Real> discrete_field_u_;
00196
00197  Real west_bndy_x_;
00198  Real east_bndy_x_;
00199  Real num_cells_x_;
00200  Real delta_x_;
00201 };
00202 }
00203 #endif // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_

```

17.47 include/mtk_uni_stg_grid_2d.h File Reference

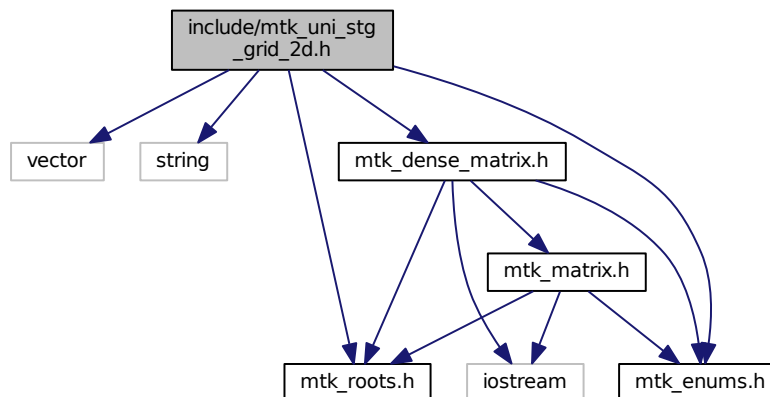
Definition of an 2D uniform staggered grid.

```

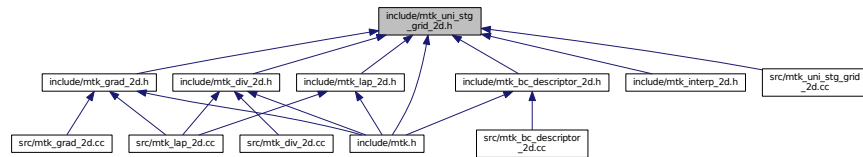
#include <vector>
#include <string>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_dense_matrix.h"

```

Include dependency graph for mtk_uni_stg_grid_2d.h:



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



Classes

- class [mtk::UniStgGrid2D](#)
Uniform 2D Staggered Grid.

Namespaces

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

17.47.1 Detailed Description

Definition of an 2D uniform staggered grid.

Author

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

Todo Create overloaded binding routines that read data from files.

Definition in file [mtk_uni_stg_grid_2d.h](#).

17.48 mtk_uni_stg_grid_2d.h

```

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:
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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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```



```

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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00054 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_UNI_STG_GRID_2D_H_
00059 #define MTK_INCLUDE_UNI_STG_GRID_2D_H_
00060
00061 #include <vector>
00062 #include <string>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_enums.h"
00066 #include "mtk_dense_matrix.h"
00067
00068 namespace mtk {
00069
00070 class UniStgGrid2D {
00071 public:
00072     friend std::ostream& operator <<(std::ostream& stream, UniStgGrid2D &in);
00073
00074     UniStgGrid2D();
00075
00076     UniStgGrid2D(const UniStgGrid2D &grid);
00077
00078     UniStgGrid2D(const Real &west_bndy_x,
00079                  const Real &east_bndy_x,
00080                  const int &num_cells_x,
00081                  const Real &south_bndy_y,
00082                  const Real &north_bndy_y,
00083                  const int &num_cells_y,
00084                  const mtk::FieldNature &nature =
00085                      mtk::SCALAR);
00086
00087     ~UniStgGrid2D();
00088
00089     const Real *discrete_domain_x() const;
00090
00091     const Real *discrete_domain_y() const;
00092
00093     const Real *discrete_field() const;
00094
00095     FieldNature nature() const;
00096
00097     Real west_bndy() const;
00098
00099     Real east_bndy() const;
00100
00101     int num_cells_x() const;
00102
00103     Real delta_x() const;
00104
00105     Real south_bndy() const;
00106
00107     Real north_bndy() const;
00108
00109     int num_cells_y() const;
00110
00111     Real delta_y() const;
00112
00113     void BindScalarField(Real (*ScalarField)(Real xx, Real yy));

```

```

00214
00229 void BindVectorField(Real (*VectorFieldPComponent) (Real xx,
Real yy),
00230                      Real (*VectorFieldQComponent) (Real xx,Real yy));
00231
00244 bool WriteToFile(std::string filename,
00245                  std::string space_name_x,
00246                  std::string space_name_y,
00247                  std::string field_name) const;
00248
00249 private:
00262 void BindVectorFieldPComponent (
00263     Real (*VectorFieldPComponent) (Real xx, Real yy));
00264
00277 void BindVectorFieldQComponent (
00278     Real (*VectorFieldQComponent) (Real xx, Real yy));
00279
00280
00281 std::vector<Real> discrete_domain_x_;
00282 std::vector<Real> discrete_domain_y_;
00283 std::vector<Real> discrete_field_;
00284
00285 FieldNature nature_;
00286
00287 Real west_bndy_;
00288 Real east_bndy_;
00289 int num_cells_x_;
00290 Real delta_x_;
00291
00292 Real south_bndy_;
00293 Real north_bndy_;
00294 int num_cells_y_;
00295 Real delta_y_;
00296 };
00297 }
00298 #endif // End of: MTK_INCLUDE_UNI_STG_GRID_2D_H_

```

17.49 Makefile.inc File Reference

17.50 Makefile.inc

```

00001 # Makefile setup file for MTK.
00002
00003 SHELL := /bin/bash
00004
00005 # Please set the following variables up:
00006
00007 # 1. Absolute path to base directory of the MTK.
00008 # _____
00009
00010 BASE = /home/esanchez/Dropbox/MTK
00011
00012 # 2. The machine (platform) identifier and required machine precision.
00013 # _____
00014
00015 # Options are:
00016 # - LINUX: A LINUX box installation.
00017 # - OSX: Uses OS X optimized solvers.
00018
00019 PLAT = LINUX
00020
00021 # Options are:
00022 # - SINGLE: Use 4 B floating point numbers.
00023 # - DOUBLE: Use 8 B floating point numbers.
00024
00025 PRECISION = DOUBLE
00026
00027 # 3. Optimized solvers and operations by means of ATLAS in Linux?
00028 # _____
00029
00030 # If you have selected OSX in step 1, then you don't need to worry about this.
00031
00032 # Options are ON xor OFF:
00033
00034 ATL_OPT = OFF

```

```

00035
00036 # 4. Paths to dependencies (header files for compiling).
00037 #
00038
00039 # GLPK include path (soon to go):
00040
00041 GLPK_INC = $(HOME)/Libraries/glpk-4.35/include
00042
00043 # Linux: If ATLAS optimization is ON, users should only provide the path to
00044 # ATLAS:
00045
00046 ATLAS_INC = $(HOME)/Libraries/ATLAS_3.8.4-CORE/include
00047
00048 # OS X: Do nothing.
00049
00050 # 5. Paths to dependencies (archive files for (static) linking).
00051 #
00052
00053 # GLPK linking path (soon to go):
00054
00055 GLPK_LIB = $(HOME)/Libraries/glpk-4.35/lib/lib64/libglpk.a
00056
00057 # If optimization is OFF, then provide the paths for:
00058
00059 BLAS_LIB = $(HOME)/Libraries/BLAS-3.5.0/libblas.a
00060 LAPACK_LIB = $(HOME)/Libraries/lapack-3.5.0/liblapack.a
00061
00062 # WARNING: Vendor libraries should be used whenever they are available.
00063
00064 # However, if optimization is ON, please provide the path the ATLAS' archive:
00065
00066 ATLAS_LIB = $(HOME)/Libraries/ATLAS_3.8.4-CORE/ATLAS_3.8.4-BUILD-Citadel/lib
00067
00068 # 6. Compiler and its flags.
00069 #
00070
00071 CC = g++
00072
00073 # Debug Level. Options are:
00074 # 0. NO debug at all NOR any run-time checks... be cautious!
00075 # 1. Verbose (execution messages) AND run-time checks.
00076 # 2. Level 1 plus intermediate scalar-valued results.
00077 # 3. Level 2 plus intermediate array-valued results.
00078
00079 DEBUG_LEVEL = 3
00080
00081 # Flags recommended for release code:
00082
00083 CFLAGS = -Wall -O3
00084
00085 # Flags recommended for debugging code:
00086
00087 CFLAGS = -Wall -g
00088
00089 # 7. Archiver, its flags, and ranlib:
00090 #
00091
00092 ARCH = ar
00093 ARCHFLAGS = cr
00094
00095 # If your system does not have "ranlib" then set: "RANLIB = echo":
00096
00097 RANLIB = echo
00098
00099 # But, if possible:
00100
00101 RANLIB = ranlib
00102
00103 # 8. Valgrind's memcheck options (optional):
00104 #
00105
00106 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00107 --track-origins=yes --freelist-vol=20000000
00108
00109 # Done! User, please, do not mess with the definitions from this point on.
00110
00111 #
00112 #
00113 #
00114
00115 # MTK-related.

```

```

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

```

17.51 README.md File Reference

17.52 README.md

```

00001 # The Mimetic Methods Toolkit (MTK)
00002
00003 By: **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu**
00004
00005
00006 ## 1. Description
00007
00008 We define numerical methods that are based on discretizations preserving the
00009 properties of their continuum counterparts to be **mimetic**.
00010
00011 The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical
00012 methods. It is arranged as a set of classes for **mimetic quadratures**,
00013 **mimetic interpolation**, and **mimetic finite differences** methods for the

```

```

00014 numerical solution of ordinary and partial differential equations.
00015
00016 An older version of this library is available outside of GitHub... just email me
00017 about it, and you can have it... it is ugly, yet it is functional and more
00018 complete.
00019
00020
00021 ## 2. Dependencies
00022
00023 This README assumes all of these dependencies are installed in the following
00024 folder:
00025
00026 ```
00027 $(HOME)/Libraries/
00028 ```
00029
00030 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00031 routines for the internal computation on some of the layers. However, ATLAS
00032 requires both BLAS and LAPACK in order to create their optimized distributions.
00033 Therefore, the following dependencies tree arises:
00034
00035 ### For Linux:
00036
00037 1. LAPACK - Available from: http://www.netlib.org/lapack/
00038   1. BLAS - Available from: http://www.netlib.org/blas/
00039
00040 2. GLPK - Available from: https://www.gnu.org/software/glpk/
00041
00042 3. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00043   1. LAPACK - Available from: http://www.netlib.org/lapack/
00044   1. BLAS - Available from: http://www.netlib.org/blas/
00045
00046 4. (Optional) Valgrind - Available from: http://valgrind.org/
00047
00048 5. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00049
00050 ### For OS X:
00051
00052 1. GLPK - Available from: https://www.gnu.org/software/glpk/
00053
00054
00055 ## 3. Installation
00056
00057 ### PART 1. CONFIGURATION OF THE MAKEFILE.
00058
00059 The following steps are required to build and test the MTK. Please use the
00060 accompanying 'Makefile.inc' file, which should provide a solid template to
00061 start with. The following command provides help on the options for make:
00062
00063 ```
00064 $ make help
00065 -----
00066 Makefile for the MTK.
00067
00068 Options are:
00069 - all: builds the library, the tests, and examples.
00070 - mtklib: builds the library.
00071 - test: builds the test files.
00072 - example: builds the examples.
00073
00074 - testall: runs all the tests.
00075
00076 - gendoc: generates the documentation for the library.
00077
00078 - clean: cleans all the generated files.
00079 - cleanlib: cleans the generated archive and object files.
00080 - cleantest: cleans the generated tests executables.
00081 - cleanexample: cleans the generated examples executables.
00082 -----
00083 ```
00084
00085 ### PART 2. BUILD THE LIBRARY.
00086
00087 ```
00088 $ make
00089 ```
00090
00091 If successful you'll read (before building the tests and examples):
00092
00093 ```
00094 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib

```

```

00095 ```
00096
00097 Examples and tests will also be built.
00098
00099
00100 ## 4. Frequently Asked Questions
00101
00102 Q: Why haven't you guys implemented GBS to build the library?
00103 A: I'm on it as we speak! ;)
00104
00105 Q: Is there any main reference when it comes to the theory on Mimetic Methods?
00106 A: Yes! Check: http://www.csrc.sdsu.edu/mimetic-book
00107
00108 Q: Do I need to generate the documentation myself?
00109 A: You can if you want to... but if you DO NOT want to, just go to our website.
00110
00111
00112 ## 5. Contact, Support, and Credits
00113
00114 The MTK is developed by researchers and adjuncts to the
00115 [Computational Science Research Center (CSRC)](http://www.csrc.sdsu.edu/)
00116 at [San Diego State University (SDSU)](http://www.sdsu.edu/).
00117
00118 Developers are members of:
00119
00120 1. Mimetic Numerical Methods Research and Development Group.
00121 2. Computational Geoscience Research and Development Group.
00122 3. Ocean Modeling Research and Development Group.
00123
00124 Currently the developers are:
00125
00126 - **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00127 - Jose E. Castillo, Ph.D. - jcastillo at mail dot sdsu dot edu
00128 - Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
00129 - Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
00130 - Angel Boada.
00131 - Johnny Corbino.
00132 - Raul Vargas-Navarro.
00133
00134 Finally, please feel free to contact me with suggestions or corrections:
00135
00136 **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00137
00138 Thanks and happy coding!

```

17.53 src/mtk_bc_descriptor_1d.cc File Reference

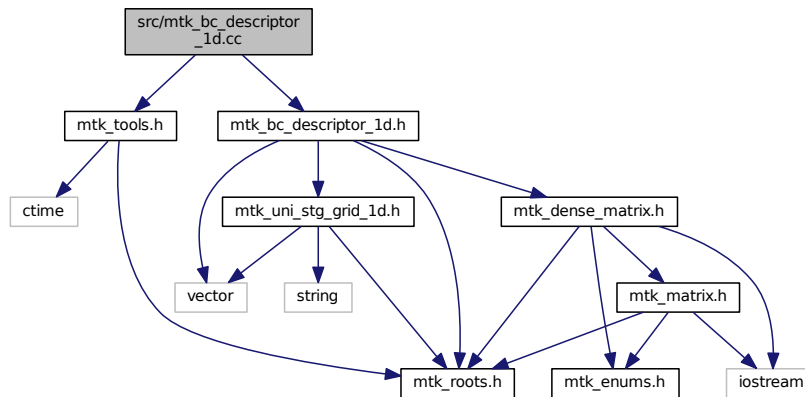
Enforces boundary conditions in either the operator or the grid.

```

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

```

Include dependency graph for mtk_bc_descriptor_1d.cc:



17.53.1 Detailed Description

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

Author

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

Definition in file [mtk_bc_descriptor_1d.cc](#).

17.54 mtk_bc_descriptor_1d.cc

```

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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.
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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 "mtk_tools.h"
00058
00059 #include "mtk_bc_descriptor_1d.h"
00060
00061 void mtk::BCDescriptor1D::ImposeOnLaplacianMatrix(
00062     mtk::DenseMatrix &matrix,
00063     const std::vector<mtk::Real> &west,
00064     const std::vector<mtk::Real> &east) {
00065
00066     #if MTK_DEBUG_LEVEL > 0
00067         mtk::Tools::Prevent(matrix.num_rows() == 0, __FILE__, __LINE__, __func__);
00068         mtk::Tools::Prevent(west.size() > (unsigned int) matrix.
00069             num_cols(),
00070             __FILE__, __LINE__, __func__);
00071         mtk::Tools::Prevent(east.size() > (unsigned int) matrix.
00072             num_cols(),
00073             __FILE__, __LINE__, __func__);
00074     #endif
00075
00076     for (unsigned int ii = 0; ii < west.size(); ++ii) {
00077         matrix.SetValue(0, ii, west[ii]);
00078     }
00079
00080     for (unsigned int ii = 0; ii < east.size(); ++ii) {
00081         matrix.SetValue(matrix.num_rows() - 1,
00082             matrix.num_cols() - 1 - ii,
00083             east[ii]);
00084     }
00085 }
00086
00087 void mtk::BCDescriptor1D::ImposeOnGrid(
00088     mtk::UniStgGrid1D &grid,
00089     const mtk::Real &omega,
00090     const mtk::Real &epsilon) {
00091
00092     #if MTK_DEBUG_LEVEL > 0
00093         mtk::Tools::Prevent(grid.num_cells_x() == 0, __FILE__, __LINE__, __func__);
00094     #endif
00095
00096     grid.discrete_field_u()[0] = omega;
00097
00098     grid.discrete_field_u()[grid.num_cells_x() + 2 - 1] = epsilon;
00099 }

```

17.55 src/mtk_bc_descriptor_2d.cc File Reference

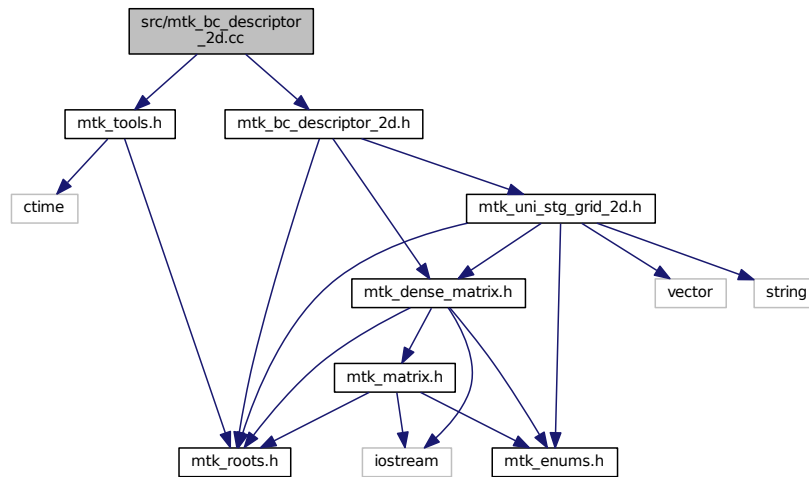
Enforces boundary conditions in either the operator or the grid.

```

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

```


Include dependency graph for mtk_bc_descriptor_2d.cc:



17.55.1 Detailed Description

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

Author

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

Definition in file [mtk_bc_descriptor_2d.cc](#).

17.56 mtk_bc_descriptor_2d.cc

```

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00022 should be developed and included in any deliverable.
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00055 */
00056
00057 #include "mtk_tools.h"
00058 #include "mtk_bc_descriptor_2d.h"

```

17.57 src/mtk_blas_adapter.cc File Reference

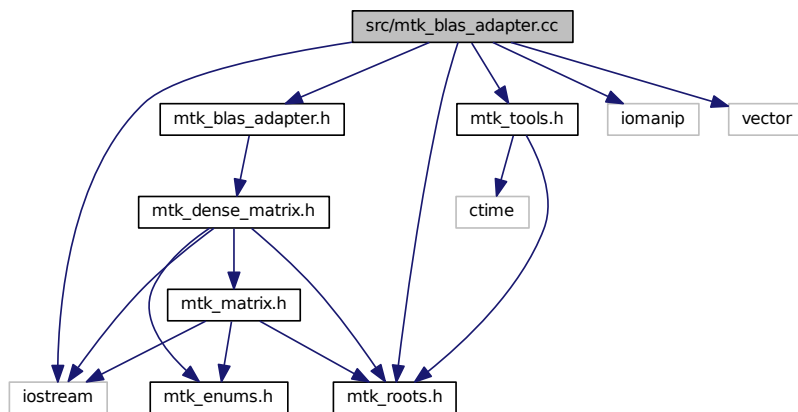
Adapter class for the BLAS API.

```

#include <iostream>
#include <iomanip>
#include <vector>
#include "mtk_roots.h"
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"

```

Include dependency graph for mtk_blas_adapter.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

- float `mtk::snrm2_` (int *n, float *x, int *incx)
- void `mtk::saxpy_` (int *n, float *sa, float *sx, int *incx, float *sy, int *incy)
- void `mtk::sgemv_` (char *trans, int *m, int *n, float *alpha, float *a, int *lda, float *x, int *incx, float *beta, float *y, int *incy)
- void `mtk::sgemm_` (char *transa, char *transb, int *m, int *n, int *k, double *alpha, double *a, int *lda, double *b, aamm int *ldb, double *beta, double *c, int *ldc)

17.57.1 Detailed Description

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

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

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

See also

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

Author

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

Definition in file [mtk_blas_adapter.cc](#).

17.58 mtk_blas_adapter.cc

```
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00032 and a copy of the modified files should be reported once modifications are
00033 completed, unless these modifications are made through the project's GitHub
00034 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00035 should be developed and included in any deliverable.
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00068 */
00069
00070 #include <iostream>
00071 #include <iomanip>
00072
00073 #include <vector>
00074
00075 #include "mtk_roots.h"
00076 #include "mtk_tools.h"
00077 #include "mtk_blas_adapter.h"
00078
00079 namespace mtk {
00080
00081 extern "C" {
00082
00083 #ifdef MTK_PRECISION_DOUBLE
00084
00097 double dnrms2_(int *n, double *x, int *incx);
00098 #else
00099
00112 float snrms2_(int *n, float *x, int *incx);
00113 #endif
00114
00115 #ifdef MTK_PRECISION_DOUBLE
00116
00135 void daxpy_(int *n, double *da, double *dx, int *incx, double *dy, int *incy);
00136 #else
00137
00156 void saxpy_(int *n, float *sa, float *sx, int *incx, float *sy, int *incy);
00157 #endif
00158
00159 #ifdef MTK_PRECISION_DOUBLE
00160
00188 void dgemv_(char *trans,
00189             int *m,
00190             int *n,
00191             double *alpha,
00192             double *a,
00193             int *lda,
00194             double *x,
00195             int *incx,
00196             double *beta,
00197             double *y,
00198             int *incy);
00199 #else
00200
00228 void sgemv_(char *trans,
00229             int *m,
00230             int *n,
00231             float *alpha,
00232             float *a,
00233             int *lda,
00234             float *x,
00235             int *incx,
00236             float *beta,
00237             float *y,
00238             int *incy);
00239 #endif
00240
00241 #ifdef MTK_PRECISION_DOUBLE
00242

```

```

00267 void dgemm_(char *transa,
00268             char* transb,
00269             int *m,
00270             int *n,
00271             int *k,
00272             double *alpha,
00273             double *a,
00274             int *lda,
00275             double *b,
00276             int *ldb,
00277             double *beta,
00278             double *c,
00279             int *ldc);
00280 }
00281 #else
00282
00307 void sgemm_(char *transa,
00308             char* transb,
00309             int *m,
00310             int *n,
00311             int *k,
00312             double *alpha,
00313             double *a,
00314             int *lda,
00315             double *b, aamm
00316             int *ldb,
00317             double *beta,
00318             double *c,
00319             int *ldc);
00320 }
00321 #endif
00322 }
00323
00324 mtk::Real mtk::BLASAdapter::RealNRM2(Real *in, int &in_length) {
00325
00326     #if MTK_DEBUG_LEVEL > 0
00327     mtk::Tools::Prevent(in_length <= 0, __FILE__, __LINE__, __func__);
00328     #endif
00329
00330     int incx{1}; // Increment for the elements of xx. ix >= 0.
00331
00332     #ifdef MTK_PRECISION_DOUBLE
00333     return dnm2_(&in_length, in, &incx);
00334     #else
00335     return snrm2_(&in_length, in, &incx);
00336     #endif
00337 }
00338
00339 void mtk::BLASAdapter::RealAXPY(mtk::Real alpha,
00340                                mtk::Real *xx,
00341                                mtk::Real *yy,
00342                                int &in_length) {
00343
00344     #if MTK_DEBUG_LEVEL > 0
00345     mtk::Tools::Prevent(xx == nullptr, __FILE__, __LINE__, __func__);
00346     mtk::Tools::Prevent(yy == nullptr, __FILE__, __LINE__, __func__);
00347     #endif
00348
00349     int incx{1}; // Increment for the elements of xx. ix >= 0.
00350
00351     #ifdef MTK_PRECISION_DOUBLE
00352     daxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00353     #else
00354     saxpy_(&in_length, &alpha, xx, &incx, yy, &incx);
00355     #endif
00356 }
00357
00358 mtk::Real mtk::BLASAdapter::RelNorm2Error(
00359     mtk::Real *computed,
00360     mtk::Real *known,
00361     int length) {
00362
00363     #if MTK_DEBUG_LEVEL > 0
00364     mtk::Tools::Prevent(computed == nullptr, __FILE__, __LINE__, __func__);
00365     mtk::Tools::Prevent(known == nullptr, __FILE__, __LINE__, __func__);
00366     #endif
00367
00368     mtk::Real norm_2_computed{mtk::BLASAdapter::RealNRM2(known, length)};
00369
00370     mtk::Real alpha{-mtk::kOne};

```

```

00371     mtk::BLASAdapter::RealAXPY(alpha, known, computed, length);
00372
00373     mtk::Real norm_2_difference{mtk::BLASAdapter::RealNRM2(computed,
length)};
00374
00375     return norm_2_difference/norm_2_computed;
00376 }
00377
00378 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00379                                     mtk::DenseMatrix &aa,
00380                                     mtk::Real *xx,
00381                                     mtk::Real &beta,
00382                                     mtk::Real *yy) {
00383
00384     // Make sure input matrices are row-major ordered.
00385
00386     if (aa.matrix_properties().ordering() ==
mtk::COL_MAJOR) {
00387         aa.OrderRowMajor();
00388     }
00389
00390     char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00391
00392     int mm{aa.num_rows()}; // Rows of aa.
00393     int nn{aa.num_cols()}; // Columns of aa.
00394     int lda{aa.matrix_properties().ld()}; // Leading dimension.
00395     int incx{1}; // Increment of values in x.
00396     int incy{1}; // Increment of values in y.
00397
00398     std::swap(mm,nn);
00399     #ifdef MTK_PRECISION_DOUBLE
00400     dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00401           xx, &incx, &beta, yy, &incy);
00402     #else
00403     sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00404           xx, &incx, &beta, yy, &incy);
00405     #endif
00406     std::swap(mm,nn);
00407 }
00408
00409 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
mtk::DenseMatrix &aa,
00410                                     mtk::DenseMatrix &bb) {
00411
00412     #if MTK_DEBUG_LEVEL > 0
00413     mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00414                         __FILE__, __LINE__, __func__);
00415     #endif
00416
00417     // Make sure input matrices are row-major ordered.
00418
00419     if (aa.matrix_properties().ordering() ==
mtk::COL_MAJOR) {
00420         aa.OrderRowMajor();
00421     }
00422     if (bb.matrix_properties().ordering() ==
mtk::COL_MAJOR) {
00423         bb.OrderRowMajor();
00424     }
00425
00426     char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00427     char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00428
00429     int mm{aa.num_rows()}; // Rows of aa and rows of cc.
00430     int nn{bb.num_cols()}; // Cols of bb and cols of cc.
00431     int kk{aa.num_cols()}; // Cols of aa and rows of bb.
00432
00433     int cc_num_rows{mm}; // Rows of cc.
00434     int cc_num_cols{nn}; // Columns of cc.
00435
00436     int lda{std::max(1, kk)}; // Leading dimension of the aa matrix.
00437     int ldb{std::max(1, nn)}; // Leading dimension of the bb matrix.
00438     int ldc{std::max(1, mm)}; // Leading dimension of the cc matrix.
00439
00440     mtk::Real alpha{1.0}; // First scalar coefficient.
00441     mtk::Real beta{0.0}; // Second scalar coefficient.
00442
00443     mtk::DenseMatrix cc_col_maj_ord(cc_num_rows, cc_num_cols); // Output matrix.
00444
00445     cc_col_maj_ord.SetOrdering(mtk::COL_MAJOR);
00446

```

```

00447  #ifdef MTK_PRECISION_DOUBLE
00448  dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00449        bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00450  #else
00451  sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00452        bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00453  #endif
00454
00455  #if MTK_DEBUG_LEVEL > 0
00456  std::cout << "cc_col_maj_ord =" << std::endl;
00457  std::cout << cc_col_maj_ord << std::endl;
00458  #endif
00459
00460  cc_col_maj_ord.OrderRowMajor();
00461
00462  return cc_col_maj_ord;
00463 }

```

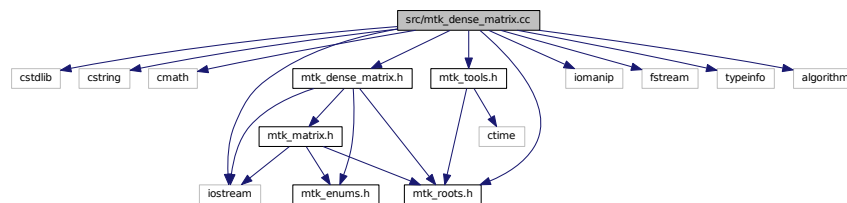
17.59 src/mtk_dense_matrix.cc File Reference

```

#include <cstdlib>
#include <cstring>
#include <cmath>
#include <iostream>
#include <iomanip>
#include <fstream>
#include <typeinfo>
#include <algorithm>
#include "mtk_roots.h"
#include "mtk_dense_matrix.h"
#include "mtk_tools.h"

```

Include dependency graph for mtk_dense_matrix.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

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

17.60 mtk_dense_matrix.cc

```

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00023 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00024 should be developed and included in any deliverable.
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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 <algorithm>
00070
00071 #include "mtk_roots.h"
00072 #include "mtk_dense_matrix.h"
00073 #include "mtk_tools.h"
00074
00075 namespace mtk {
00076
00077 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00078
00079     int mm{in.matrix_properties_.num_rows()}; // Auxiliary.
00080     int nn{in.matrix_properties_.num_cols()}; // Auxiliary.
00081
00082     if (in.matrix_properties_.ordering() ==
00083         mtk::COL_MAJOR) {
00084         std::swap(mm, nn);
00085     }
00086     for (int ii = 0; ii < mm; ii++) {
00087         int offset{ii*nn};
00088         for (int jj = 0; jj < nn; jj++) {
00089             mtk::Real value = in.data_[offset + jj];

```



```

00089         stream << std::setw(9) << value;
00090     }
00091     stream << std::endl;
00092 }
00093 if (in.matrix_properties_.ordering() ==
mtk::COL_MAJOR) {
00094     std::swap(mm, nn);
00095 }
00096 return stream;
00097 }
00098 }
00099
00100 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
mtk::DenseMatrix &in) {
00101
00102     if(this == &in) {
00103         return *this;
00104     }
00105
00106     matrix_properties_.set_storage(in.
matrix_properties_.storage());
00107
00108     matrix_properties_.set_ordering(in.
matrix_properties_.ordering());
00109
00110     auto aux = in.matrix_properties_.num_rows();
00111     matrix_properties_.set_num_rows(aux);
00112
00113     aux = in.matrix_properties().num_cols();
00114     matrix_properties_.set_num_cols(aux);
00115
00116     aux = in.matrix_properties().num_zero();
00117     matrix_properties_.set_num_zero(aux);
00118
00119     aux = in.matrix_properties().num_null();
00120     matrix_properties_.set_num_null(aux);
00121
00122     auto num_rows = matrix_properties_.num_rows();
00123     auto num_cols = matrix_properties_.num_cols();
00124
00125     delete [] data_;
00126
00127     try {
00128         data_ = new mtk::Real[num_rows*num_cols];
00129     } catch (std::bad_alloc &memory_allocation_exception) {
00130         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00131             std::endl;
00132         std::cerr << memory_allocation_exception.what() << std::endl;
00133     }
00134     memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*
num_cols);
00135
00136     std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00137
00138     return *this;
00139 }
00140
00141 bool mtk::DenseMatrix::operator ==(const
DenseMatrix &in) {
00142
00143     bool ans{true};
00144
00145     auto mm = in.num_rows();
00146     auto nn = in.num_cols();
00147
00148     if (mm != matrix_properties_.num_rows() ||
nn != matrix_properties_.num_cols()) {
00149         return false;
00150     }
00151
00152     for (int ii = 0; ii < mm && ans; ++ii) {
00153         for (int jj = 0; jj < nn && ans; ++jj) {
00154             ans = ans &&
00155                 abs(data_[ii*nn + jj] - in.data()[ii*nn + jj]) <
mtk::kDefaultTolerance;
00156         }
00157     }
00158
00159     return ans;
00160 }
00161
00162 mtk::DenseMatrix::DenseMatrix(): data_(nullptr) {

```

```

00163
00164     matrix_properties_.set_storage(mtk::DENSE);
00165     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00166 }
00167
00168 mtk::DenseMatrix::DenseMatrix(const
00169     mtk::DenseMatrix &in) {
00170
00171     matrix_properties_.set_storage(in.matrix_properties_.storage());
00172     matrix_properties_.set_ordering(in.matrix_properties_.
00173         ordering());
00174
00175     auto aux = in.matrix_properties_.num_rows();
00176     matrix_properties_.set_num_rows(aux);
00177
00178     aux = in.matrix_properties().num_cols();
00179     matrix_properties_.set_num_cols(aux);
00180
00181     aux = in.matrix_properties().num_zero();
00182     matrix_properties_.set_num_zero(aux);
00183
00184     aux = in.matrix_properties().num_null();
00185     matrix_properties_.set_num_null(aux);
00186
00187     auto num_rows = in.matrix_properties_.num_rows();
00188     auto num_cols = in.matrix_properties_.num_cols();
00189
00190     try {
00191         data_ = new mtk::Real[num_rows*num_cols];
00192     } catch (std::bad_alloc &memory_allocation_exception) {
00193         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00194             std::endl;
00195         std::cerr << memory_allocation_exception.what() << std::endl;
00196     }
00197     memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00198     std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00199 }
00200
00201 mtk::DenseMatrix::DenseMatrix(const int &num_rows, const int &num_cols) {
00202
00203     #if MTK_DEBUG_LEVEL > 0
00204     mtk::Tools::Prevent(num_rows < 1, __FILE__, __LINE__, __func__);
00205     mtk::Tools::Prevent(num_cols < 1, __FILE__, __LINE__, __func__);
00206     #endif
00207
00208     matrix_properties_.set_storage(mtk::DENSE);
00209     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00210     matrix_properties_.set_num_rows(num_rows);
00211     matrix_properties_.set_num_cols(num_cols);
00212
00213     try {
00214         data_ = new mtk::Real[num_rows*num_cols];
00215     } catch (std::bad_alloc &memory_allocation_exception) {
00216         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00217             std::endl;
00218         std::cerr << memory_allocation_exception.what() << std::endl;
00219     }
00220     memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00221 }
00222
00223 mtk::DenseMatrix::DenseMatrix(const int &rank,
00224     const bool &padded,
00225     const bool &transpose) {
00226
00227     #if MTK_DEBUG_LEVEL > 0
00228     mtk::Tools::Prevent(rank < 1, __FILE__, __LINE__, __func__);
00229     #endif
00230
00231     int aux{}; // Used to control the padding.
00232
00233     if (padded) {
00234         aux = 1;
00235     }
00236
00237     matrix_properties_.set_storage(mtk::DENSE);
00238     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00239     matrix_properties_.set_num_rows(aux + rank + aux);
00240     matrix_properties_.set_num_cols(rank);
00241

```

```

00242     try {
00243         data_ = new mtk::Real[matrix_properties_.num_values()];
00244     } catch (std::bad_alloc &memory_allocation_exception) {
00245         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00246             std::endl;
00247         std::cerr << memory_allocation_exception.what() << std::endl;
00248     }
00249     memset(data_,
00250         mtk::kZero,
00251         sizeof(data_[0])*(matrix_properties_.num_values()));
00252
00253     for (auto ii = 0; ii < matrix_properties_.num_rows(); ++ii) {
00254         for (auto jj = 0; jj < matrix_properties_.num_cols(); ++jj) {
00255             data_[ii*matrix_properties_.num_cols() + jj] =
00256                 (ii == jj + aux)? mtk::kOne: mtk::kZero;
00257         }
00258     }
00259     if (transpose) {
00260         Transpose();
00261     }
00262 }
00263
00264 mtk::DenseMatrix::DenseMatrix(const mtk::Real *gen,
00265     const int &gen_length,
00266     const int &pro_length,
00267     const bool &transpose) {
00268
00269     #if MTK_DEBUG_LEVEL > 0
00270     mtk::Tools::Prevent(gen == nullptr, __FILE__, __LINE__, __func__);
00271     mtk::Tools::Prevent(gen_length < 1, __FILE__, __LINE__, __func__);
00272     mtk::Tools::Prevent(pro_length < 1, __FILE__, __LINE__, __func__);
00273     #endif
00274
00275     matrix_properties_.set_storage(mtk::DENSE);
00276     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00277     if (!transpose) {
00278         matrix_properties_.set_num_rows(gen_length);
00279         matrix_properties_.set_num_cols(pro_length);
00280     } else {
00281         matrix_properties_.set_num_rows(pro_length);
00282         matrix_properties_.set_num_cols(gen_length);
00283     }
00284
00285     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00286     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00287
00288     try {
00289         data_ = new mtk::Real[mm*nn];
00290     } catch (std::bad_alloc &memory_allocation_exception) {
00291         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00292             std::endl;
00293         std::cerr << memory_allocation_exception.what() << std::endl;
00294     }
00295     memset(data_, mtk::kZero, sizeof(data_[0])*mm*nn);
00296
00297     if (!transpose) {
00298         for (auto ii = 0; ii < mm; ii++) {
00299             for (auto jj = 0; jj < nn; jj++) {
00300                 data_[ii*nn + jj] = pow(gen[ii], (double) jj);
00301             }
00302         }
00303     } else {
00304         for (auto ii = 0; ii < mm; ii++) {
00305             for (auto jj = 0; jj < nn; jj++) {
00306                 data_[ii*nn + jj] = pow(gen[jj], (double) ii);
00307             }
00308         }
00309     }
00310 }
00311
00312 mtk::DenseMatrix::~DenseMatrix() {
00313
00314     delete[] data_;
00315     data_ = nullptr;
00316 }
00317
00318 mtk::Matrix mtk::DenseMatrix::matrix_properties() const {
00319
00320     return matrix_properties_;
00321 }
00322

```

```

00323 void mtk::DenseMatrix::SetOrdering(
    mtk::MatrixOrdering oo) {
00324
00325     #if MTK_DEBUG_LEVEL > 0
00326     mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
    mtk::COL_MAJOR),
00327         __FILE__, __LINE__, __func__);
00328     #endif
00329
00330     matrix_properties_.set_ordering(oo);
00331 }
00332
00333 int mtk::DenseMatrix::num_rows() const {
00334     return matrix_properties_.num_rows();
00335 }
00336
00337 int mtk::DenseMatrix::num_cols() const {
00338     return matrix_properties_.num_cols();
00339 }
00340
00341 mtk::Real* mtk::DenseMatrix::data() const {
00342     return data_;
00343 }
00344
00345 mtk::Real mtk::DenseMatrix::GetValue(
    const int &mm,
    const int &nn) const {
00346     #if MTK_DEBUG_LEVEL > 0
00347     mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00348     mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00349     #endif
00350     return data_[mm*matrix_properties_.num_cols() + nn];
00351 }
00352
00353 void mtk::DenseMatrix::SetValue(
    const int &mm,
    const int &nn,
    const mtk::Real &val) {
00354     #if MTK_DEBUG_LEVEL > 0
00355     mtk::Tools::Prevent(mm < 0, __FILE__, __LINE__, __func__);
00356     mtk::Tools::Prevent(nn < 0, __FILE__, __LINE__, __func__);
00357     #endif
00358     data_[mm*matrix_properties_.num_cols() + nn] = val;
00359 }
00360
00361 void mtk::DenseMatrix::Transpose() {
00362
00363     mtk::Real *data_transposed{}; // Buffer.
00364
00365     int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00366     int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00367
00368     try {
00369         data_transposed = new mtk::Real[mm*nn];
00370     } catch (std::bad_alloc &memory_allocation_exception) {
00371         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
            std::endl;
00372         std::cerr << memory_allocation_exception.what() << std::endl;
00373     }
00374     memset(data_transposed,
00375         mtk::kZero,
00376         sizeof(data_transposed[0])*mm*nn);
00377
00378     // Assign the values to their transposed position.
00379     for (auto ii = 0; ii < mm; ++ii) {
00380         for (auto jj = 0; jj < nn; ++jj) {
00381             data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00382         }
00383     }
00384
00385     // Swap pointers.
00386     auto tmp = data_; // Temporal holder.
00387     data_ = data_transposed;

```

```

00403     delete [] tmp;
00404     tmp = nullptr;
00405
00406     matrix_properties_.set_num_rows(nn);
00407     matrix_properties_.set_num_cols(mm);
00408 }
00409
00410 void mtk::DenseMatrix::OrderRowMajor() {
00411
00412     if (matrix_properties_.ordering() == mtk::COL_MAJOR) {
00413
00414
00415         mtk::Real *data_transposed{}; // Buffer.
00416
00417         int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00418         int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00419
00420         try {
00421             data_transposed = new mtk::Real[mm*nn];
00422         } catch (std::bad_alloc &memory_allocation_exception) {
00423             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00424                 std::endl;
00425             std::cerr << memory_allocation_exception.what() << std::endl;
00426         }
00427         memset(data_transposed,
00428             mtk::kZero,
00429             sizeof(data_transposed[0])*mm*nn);
00430
00431         // Assign the values to their transposed position.
00432         std::swap(mm, nn);
00433         for (auto ii = 0; ii < mm; ++ii) {
00434             for (auto jj = 0; jj < nn; ++jj) {
00435                 data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00436             }
00437         }
00438         std::swap(mm, nn);
00439
00440         // Swap pointers.
00441         auto tmp = data_; // Temporal holder.
00442         data_ = data_transposed;
00443         delete [] tmp;
00444         tmp = nullptr;
00445
00446         matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00447     }
00448 }
00449 }
00450
00451 void mtk::DenseMatrix::OrderColMajor() {
00452
00453     if (matrix_properties_.ordering() == ROW_MAJOR) {
00454
00455
00456         mtk::Real *data_transposed{}; // Buffer.
00457
00458         int mm = matrix_properties_.num_rows(); // Used to construct this matrix.
00459         int nn = matrix_properties_.num_cols(); // Used to construct this matrix.
00460
00461         try {
00462             data_transposed = new mtk::Real[mm*nn];
00463         } catch (std::bad_alloc &memory_allocation_exception) {
00464             std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00465                 std::endl;
00466             std::cerr << memory_allocation_exception.what() << std::endl;
00467         }
00468         memset(data_transposed,
00469             mtk::kZero,
00470             sizeof(data_transposed[0])*mm*nn);
00471
00472         // Assign the values to their transposed position.
00473         for (auto ii = 0; ii < mm; ++ii) {
00474             for (auto jj = 0; jj < nn; ++jj) {
00475                 data_transposed[jj*mm + ii] = data_[ii*nn + jj];
00476             }
00477         }
00478
00479         // Swap pointers.
00480         auto tmp = data_; // Temporal holder.
00481         data_ = data_transposed;
00482         delete [] tmp;
00483         tmp = nullptr;
00484
00485

```

```

00486     matrix_properties_.set_ordering(mtk::COL_MAJOR);
00487 }
00488 }
00489
00490 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
    mtk::DenseMatrix &aa,
00491                                     const mtk::DenseMatrix &bb) {
00492
00493     int row_offset{}; // Offset for rows.
00494     int col_offset{}; // Offset for rows.
00495
00496     mtk::Real aa_factor{}; // Used in computation.
00497
00498     // Auxiliary variables:
00499     auto aux1 = aa.matrix_properties_.num_rows()*bb.
matrix_properties_.num_rows();
00500     auto aux2 = aa.matrix_properties_.num_cols()*bb.
matrix_properties_.num_cols();
00501
00502     mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00503
00504     int kk_num_cols(output.matrix_properties_.num_cols()); // Aux.
00505
00506     auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00507     auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00508     auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00509     auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00510
00511     for (auto ii = 0; ii < mm; ++ii) {
00512         row_offset = ii*pp;
00513         for (auto jj = 0; jj < nn; ++jj) {
00514             col_offset = jj*qq;
00515             aa_factor = aa.data_[ii*nn + jj];
00516             for (auto ll = 0; ll < pp; ++ll) {
00517                 for (auto oo = 0; oo < qq; ++oo) {
00518                     auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00519                     output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00520                 }
00521             }
00522         }
00523     }
00524
00525     output.matrix_properties_.set_storage(mtk::DENSE);
00526     output.matrix_properties_.set_ordering(
mtk::ROW_MAJOR);
00527
00528     return output;
00529 }
00530
00531 bool mtk::DenseMatrix::WriteToFile(std::string filename) const {
00532
00533     std::ofstream output_dat_file; // Output file.
00534
00535     output_dat_file.open(filename);
00536
00537     if (!output_dat_file.is_open()) {
00538         return false;
00539     }
00540
00541     int mm(matrix_properties_.num_rows());
00542     int nn(matrix_properties_.num_cols());
00543
00544     for (int ii = 0; ii < mm; ++ii) {
00545         int offset(ii*nn);
00546         for (int jj = 0; jj < nn; ++jj) {
00547             output_dat_file << ii << ' ' << jj << ' ' << data_[offset + jj] <<
std::endl;
00548         }
00549     }
00550
00551     output_dat_file.close();
00552
00553     return true;
00554 }
00555 }

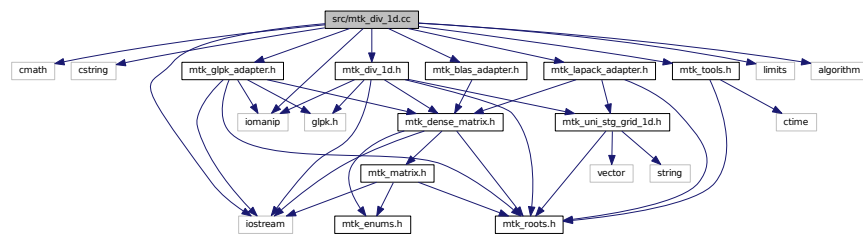
```

17.61 src/mtk_div_1d.cc File Reference

Implements the class Div1D.

```
#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_div_1d.h"
```

Include dependency graph for mtk_div_1d.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

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

17.61.1 Detailed Description

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

Author

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

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

Definition in file [mtk_div_1d.cc](#).

17.62 mtk_div_1d.cc

```

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00015 /*
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074
00075 #include "mtk_div_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Div1D &in) {
00080
00082
00083     stream << "divergence_[0] = " << std::setw(9) << in.divergence_[0] <<
00084         std::endl;
00085
00087
00088     stream << "divergence_[1:" << in.order_accuracy_ << "]" = ";
00089     for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00090         stream << std::setw(9) << in.divergence_[ii] << " ";
00091     }
00092     stream << std::endl;
00093

```



```

00094     if (in.order_accuracy_ > 2) {
00095
00096
00097         stream << "divergence_" << in.order_accuracy_ + 1 << ":" <<
00098             2*in.order_accuracy_ << "]" = ";
00099         for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
00100             order_accuracy_; ++ii) {
00101             stream << std::setw(9) << in.divergence_[ii] << " ";
00102         }
00103         stream << std::endl;
00104
00105
00106         auto offset = (2*in.order_accuracy_ + 1);
00107         int mm{};
00108         for (auto ii = 0; ii < in.dim_null_; ++ii) {
00109             stream << "divergence_" << offset + mm << ":" <<
00110                 offset + mm + in.num_bndy_coeffs_ - 1 << "]" = ";
00111             for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00112                 auto value = in.divergence_[offset + mm];
00113                 stream << std::setw(9) << value << " ";
00114                 ++mm;
00115             }
00116             stream << std::endl;
00117         }
00118     }
00119 }
00120
00121 return stream;
00122 }
00123 }
00124
00125 mtk::Div1D::Div1D():
00126     order_accuracy_(mtk::kDefaultOrderAccuracy),
00127     dim_null_(),
00128     num_bndy_coeffs_(),
00129     divergence_length_(),
00130     minrow_(),
00131     row_(),
00132     coeffs_interior_(),
00133     prem_apps_(),
00134     weights_crs_(),
00135     weights_cbs_(),
00136     mim_bndy_(),
00137     divergence_(),
00138     mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00139
00140 mtk::Div1D::Div1D(const Div1D &div):
00141     order_accuracy_(div.order_accuracy_),
00142     dim_null_(div.dim_null_),
00143     num_bndy_coeffs_(div.num_bndy_coeffs_),
00144     divergence_length_(div.divergence_length_),
00145     minrow_(div.minrow_),
00146     row_(div.row_),
00147     coeffs_interior_(div.coeffs_interior_),
00148     prem_apps_(div.prem_apps_),
00149     weights_crs_(div.weights_crs_),
00150     weights_cbs_(div.weights_cbs_),
00151     mim_bndy_(div.mim_bndy_),
00152     divergence_(div.divergence_),
00153     mimetic_threshold_(div.mimetic_threshold_) {}
00154
00155 mtk::Div1D::~~Div1D() {
00156
00157     delete[] coeffs_interior_;
00158     coeffs_interior_ = nullptr;
00159
00160     delete[] prem_apps_;
00161     prem_apps_ = nullptr;
00162
00163     delete[] weights_crs_;
00164     weights_crs_ = nullptr;
00165
00166     delete[] weights_cbs_;
00167     weights_cbs_ = nullptr;
00168
00169     delete[] mim_bndy_;
00170     mim_bndy_ = nullptr;
00171
00172     delete[] divergence_;
00173     divergence_ = nullptr;
00174 }
00175

```

```

00176 bool mtk::Div1D::ConstructDiv1D(int order_accuracy,
00177                                 mtk::Real mimetic_threshold) {
00178
00179     #if MTK_DEBUG_LEVEL > 0
00180     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00181     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00182     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00183                         __FILE__, __LINE__, __func__);
00184
00185     if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00186         std::cout << "WARNING: Numerical accuracy is critical." << std::endl;
00187     }
00188
00189     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00190     std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00191     #endif
00192
00193     order_accuracy_ = order_accuracy;
00194     mimetic_threshold_ = mimetic_threshold;
00195
00196
00197     bool abort_construction = ComputeStencilInteriorGrid();
00198
00199     #if MTK_DEBUG_LEVEL > 0
00200     if (!abort_construction) {
00201         std::cerr << "Could NOT complete stage 1." << std::endl;
00202         std::cerr << "Exiting..." << std::endl;
00203         return false;
00204     }
00205     #endif
00206
00207     // At this point, we already have the values for the interior stencil stored
00208     // in the coeffs_interior_ array.
00209
00210     // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00211     // approximation at the boundary, thus it has no weights. For this case, the
00212     // dimension of the null-space of the Vandermonde matrices used to compute the
00213     // approximating coefficients at the boundary is 0. Ergo, we compute this
00214     // number first and then decide if we must compute anything at the boundary.
00215
00216     dim_null_ = order_accuracy_/2 - 1;
00217
00218     if (dim_null_ > 0) {
00219
00220         #ifdef MTK_PRECISION_DOUBLE
00221         num_bndy_coeffs_ = (int) (3.0*(mtk::Real) order_accuracy_)/2.0);
00222         #else
00223         num_bndy_coeffs_ = (int) (3.0f*(mtk::Real) order_accuracy_)/2.0f);
00224         #endif
00225
00226         // For this we will follow recommendations given in:
00227         //
00228         // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00229         //
00230         // We will compute the QR Factorization of the transpose, as in the
00231         // following (MATLAB) pseudo-code:
00232         //
00233         // [Q,R] = qr(V'); % Full QR as defined in
00234         // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00235         //
00236         // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00237         //
00238         // However, given the nature of the Vandermonde matrices we've just
00239         // computed, they all posses the same null-space. Therefore, we impose the
00240         // convention of computing the null-space of the first Vandermonde matrix
00241         // (west boundary).
00242
00243         abort_construction = ComputeRationalBasisNullSpace();
00244
00245         #if MTK_DEBUG_LEVEL > 0
00246         if (!abort_construction) {
00247             std::cerr << "Could NOT complete stage 2.1." << std::endl;
00248             std::cerr << "Exiting..." << std::endl;
00249             return false;
00250         }
00251         #endif
00252
00253         abort_construction = ComputePreliminaryApproximations();
00254
00255
00256
00257
00258
00259

```

```

00260     #if MTK_DEBUG_LEVEL > 0
00261     if (!abort_construction) {
00262         std::cerr << "Could NOT complete stage 2.2." << std::endl;
00263         std::cerr << "Exiting..." << std::endl;
00264         return false;
00265     }
00266     #endif
00267
00269     abort_construction = ComputeWeights();
00270
00271
00272     #if MTK_DEBUG_LEVEL > 0
00273     if (!abort_construction) {
00274         std::cerr << "Could NOT complete stage 2.3." << std::endl;
00275         std::cerr << "Exiting..." << std::endl;
00276         return false;
00277     }
00278     #endif
00279
00281     abort_construction = ComputeStencilBoundaryGrid();
00282
00283
00284     #if MTK_DEBUG_LEVEL > 0
00285     if (!abort_construction) {
00286         std::cerr << "Could NOT complete stage 2.4." << std::endl;
00287         std::cerr << "Exiting..." << std::endl;
00288         return false;
00289     }
00290     #endif
00291
00292 } // End of: if (dim_null_ > 0);
00293
00295
00296 // Once we have the following three collections of data:
00297 // (a) the coefficients for the interior,
00298 // (b) the coefficients for the boundary (if it applies),
00299 // (c) and the weights (if it applies),
00300 // we will store everything in the output array:
00301
00302 abort_construction = AssembleOperator();
00303
00304 #if MTK_DEBUG_LEVEL > 0
00305 if (!abort_construction) {
00306     std::cerr << "Could NOT complete stage 3." << std::endl;
00307     std::cerr << "Exiting..." << std::endl;
00308     return false;
00309 }
00310 #endif
00311
00312 return true;
00313 }
00314
00315 int mtk::Div1D::num_bndy_coeffs() const {
00316     return num_bndy_coeffs_;
00317 }
00318
00319 mtk::Real *mtk::Div1D::coeffs_interior() const {
00320     return coeffs_interior_;
00321 }
00322
00323 mtk::Real *mtk::Div1D::weights_crs() const {
00324     return weights_crs_;
00325 }
00326
00327 mtk::Real *mtk::Div1D::weights_cbs() const {
00328     return weights_cbs_;
00329 }
00330
00331 mtk::DenseMatrix mtk::Div1D::mim_bndy() const {
00332     mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00333
00334     auto counter = 0;
00335     for (auto ii = 0; ii < dim_null_; ++ii) {
00336         for (auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00337             xx.SetValue(ii, jj, divergence_[2*order_accuracy_ + 1 + counter]);
00338         }
00339     }
00340 }

```

```

00344         counter++;
00345     }
00346 }
00347
00348 return xx;
00349 }
00350
00351 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(
00352     const UniStgGrid1D &grid) const {
00353
00354     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00355
00356     #if MTK_DEBUG_LEVEL > 0
00357     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00358     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00359     #endif
00360
00361     mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00362
00363     int dd_num_rows = nn + 2;
00364     int dd_num_cols = nn + 1;
00365     int elements_per_row = num_bndy_coeffs_;
00366     int num_extra_rows = dim_null_;
00367
00368     // Output matrix featuring sizes for divergence operators.
00369     mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00370
00371
00372
00373     auto ee_index = 0;
00374     for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00375         auto cc = 0;
00376         for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00377             if( cc >= elements_per_row) {
00378                 out.SetValue(ii, jj, mtk::kZero);
00379             } else {
00380                 out.SetValue(ii, jj, mim_bndy_[ee_index++]*inv_delta_x);
00381                 cc++;
00382             }
00383         }
00384     }
00385
00386
00387     for (auto ii = num_extra_rows + 1;
00388         ii < dd_num_rows - num_extra_rows - 1; ii++) {
00389         auto jj = ii - num_extra_rows - 1;
00390         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00391             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00392         }
00393     }
00394
00395
00396
00397     ee_index = 0;
00398     for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--) {
00399         auto cc = 0;
00400         for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00401             if( cc >= elements_per_row) {
00402                 out.SetValue(ii, jj, 0.0);
00403             } else {
00404                 out.SetValue(ii, jj, -mim_bndy_[ee_index++]*inv_delta_x);
00405                 cc++;
00406             }
00407         }
00408     }
00409
00410
00411     return out;
00412 }
00413
00414 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00415
00416
00417     mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00418
00419
00420     try {
00421         pp = new mtk::Real[order_accuracy_];
00422     } catch (std::bad_alloc &memory_allocation_exception) {
00423         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00424             std::endl;
00425         std::cerr << memory_allocation_exception.what() << std::endl;
00426     }
00427     memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00428

```

```

00429  #ifdef MTK_PRECISION_DOUBLE
00430  pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00431  #else
00432  pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00433  #endif
00434
00435  for (auto ii = 1; ii < order_accuracy_; ++ii) {
00436      pp[ii] = pp[ii - 1] + mtk::kOne;
00437  }
00438
00439  #if MTK_DEBUG_LEVEL > 0
00440  std::cout << "pp =" << std::endl;
00441  for (auto ii = 0; ii < order_accuracy_; ++ii) {
00442      std::cout << std::setw(12) << pp[ii];
00443  }
00444  std::cout << std::endl << std::endl;
00445  #endif
00446
00448
00449  bool transpose{false};
00450
00451  mtk::DenseMatrix vander_matrix(pp,
00452                                  order_accuracy_,
00453                                  order_accuracy_,
00454                                  transpose);
00455
00456  #if MTK_DEBUG_LEVEL > 0
00457  std::cout << "vander_matrix = " << std::endl;
00458  std::cout << vander_matrix << std::endl;
00459  #endif
00460
00462
00463  try {
00464      coeffs_interior_ = new mtk::Real[order_accuracy_];
00465  } catch (std::bad_alloc &memory_allocation_exception) {
00466      std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00467          std::endl;
00468      std::cerr << memory_allocation_exception.what() << std::endl;
00469  }
00470  memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00471
00472  coeffs_interior_[1] = mtk::kOne;
00473
00474  #if MTK_DEBUG_LEVEL > 0
00475  std::cout << "oo =" << std::endl;
00476  for (auto ii = 0; ii < order_accuracy_; ++ii) {
00477      std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00478  }
00479  std::cout << std::endl;
00480  #endif
00481
00483
00484  int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00485                                                  coeffs_interior_)};
00486
00487  #if MTK_DEBUG_LEVEL > 0
00488  if (!info) {
00489      std::cout << "System solved! Interior stencil attained!" << std::endl;
00490      std::cout << std::endl;
00491  }
00492  else {
00493      std::cerr << "Something wrong solving system! info = " << info << std::endl;
00494      std::cerr << "Exiting..." << std::endl;
00495      return false;
00496  }
00497  #endif
00498
00499  #if MTK_DEBUG_LEVEL > 0
00500  std::cout << "coeffs_interior_ =" << std::endl;
00501  for (auto ii = 0; ii < order_accuracy_; ++ii) {
00502      std::cout << std::setw(12) << coeffs_interior_[ii];
00503  }
00504  std::cout << std::endl << std::endl;
00505  #endif
00506
00507  delete [] pp;
00508  pp = nullptr;
00509
00510  return true;
00511 }
00512

```

```

00513 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00514
00515     mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00516
00517     try {
00518         gg = new mtk::Real[num_bndy_coeffs_];
00519     } catch (std::bad_alloc &memory_allocation_exception) {
00520         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00521             std::endl;
00522         std::cerr << memory_allocation_exception.what() << std::endl;
00523     }
00524     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00525
00526     #ifdef MTK_PRECISION_DOUBLE
00527     gg[0] = -1.0/2.0;
00528     #else
00529     gg[0] = -1.0f/2.0f;
00530     #endif
00531     for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00532         gg[ii] = gg[ii - 1] + mtk::kOne;
00533     }
00534
00535     #if MTK_DEBUG_LEVEL > 0
00536     std::cout << "gg =" << std::endl;
00537     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00538         std::cout << std::setw(12) << gg[ii];
00539     }
00540     std::cout << std::endl << std::endl;
00541     #endif
00542
00543     bool tran{true}; // Should I transpose the Vandermonde matrix.
00544
00545     mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00546
00547     #if MTK_DEBUG_LEVEL > 0
00548     std::cout << "vv_west_t =" << std::endl;
00549     std::cout << vv_west_t << std::endl;
00550     #endif
00551
00552     mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
00553         (vv_west_t));
00554
00555     #if MTK_DEBUG_LEVEL > 0
00556     std::cout << "QQ^T =" << std::endl;
00557     std::cout << qq_t << std::endl;
00558     #endif
00559
00560     int KK_num_rows_{num_bndy_coeffs_};
00561     int KK_num_cols_{dim_null_};
00562
00563     mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00564
00565     for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00566         for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00567             KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00568                 qq_t.data()[ii*num_bndy_coeffs_ + jj];
00569         }
00570     }
00571
00572     #if MTK_DEBUG_LEVEL > 0
00573     std::cout << "KK =" << std::endl;
00574     std::cout << KK << std::endl;
00575     std::cout << "KK.num_rows() =" << KK.num_rows() << std::endl;
00576     std::cout << "KK.num_cols() =" << KK.num_cols() << std::endl;
00577     std::cout << std::endl;
00578     #endif
00579
00580     // Scale thus requesting that the last entries of the attained basis for the
00581     // null-space, adopt the pattern we require.
00582     // Essentially we will implement the following MATLAB pseudo-code:
00583     // scalers = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00584     // SK = KK*scalers
00585     // where SK is the scaled null-space.
00586
00587     // In this point, we almost have all the data we need correctly allocated
00588     // in memory. We will create the matrix II_, and elements we wish to scale in

```

```

00598 // the KK array. Using the concept of the leading dimension, we could just
00599 // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00600 // GET how does it work. So I will just create a matrix with the content of
00601 // this array that we need, solve for the scalars and then scale the
00602 // whole KK:
00603
00604 // We will then create memory for that sub-matrix of KK (SUBK).
00605
00606 mtk::DenseMatrix SUBK(dim_null_,dim_null_);
00607
00608 for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00609     for (auto jj = 0; jj < dim_null_; ++jj) {
00610         SUBK.data()[ii - (num_bndy_coeffs_ - dim_null_)*dim_null_ + jj] =
00611             KK.data()[ii*dim_null_ + jj];
00612     }
00613 }
00614
00615 #if MTK_DEBUG_LEVEL > 0
00616 std::cout << "SUBK =" << std::endl;
00617 std::cout << SUBK << std::endl;
00618 #endif
00619
00620 SUBK.Transpose();
00621
00622 #if MTK_DEBUG_LEVEL > 0
00623 std::cout << "SUBK^T =" << std::endl;
00624 std::cout << SUBK << std::endl;
00625 #endif
00626
00627 bool padded{false};
00628 tran = false;
00629
00630 mtk::DenseMatrix II(dim_null_, padded, tran);
00631
00632 #if MTK_DEBUG_LEVEL > 0
00633 std::cout << "II =" << std::endl;
00634 std::cout << II << std::endl;
00635 #endif
00636
00637 // Solve the system to compute the scalars.
00638 // An example of the system to solve, for k = 8, is:
00639 //
00640 // SUBK*scalars = II_ or
00641 //
00642 // | 0.386018 -0.0339244 -0.129478 | | 1 0 0 |
00643 // | -0.119774 0.0199423 0.0558632 | *scalars = | 0 1 0 |
00644 // | 0.0155708 -0.00349546 -0.00853182 | | 0 0 1 |
00645 //
00646 // Notice this is a nrhs = 3 system.
00647 // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalars... they
00648 // will be stored in the created identity matrix.
00649 // Let us first transpose SUBK (because of LAPACK):
00650
00651 int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00652
00653 #if MTK_DEBUG_LEVEL > 0
00654 if (!info) {
00655     std::cout << "System successfully solved!" <<
00656         std::endl;
00657 } else {
00658     std::cerr << "Something went wrong solving system! info = " << info <<
00659         std::endl;
00660     std::cerr << "Exiting..." << std::endl;
00661     return false;
00662 }
00663 std::cout << std::endl;
00664 #endif
00665
00666 #if MTK_DEBUG_LEVEL > 0
00667 std::cout << "Computed scalars:" << std::endl;
00668 std::cout << II << std::endl;
00669 #endif
00670
00671 // Multiply the two matrices to attain a scaled basis for null-space.
00672
00673 rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00674
00675 #if MTK_DEBUG_LEVEL > 0
00676 std::cout << "Rational basis for the null-space:" << std::endl;
00677 std::cout << rat_basis_null_space_ << std::endl;
00678 #endif

```

```

00679
00680 // At this point, we have a rational basis for the null-space, with the
00681 // pattern we need! :)
00682
00683 delete [] gg;
00684 gg = nullptr;
00685
00686 return true;
00687 }
00688
00689 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00690
00691
00692
00693     mtk::Real *gg{}; // Generator vector for the first approximation.
00694
00695     try {
00696         gg = new mtk::Real[num_bndy_coeffs_];
00697     } catch (std::bad_alloc &memory_allocation_exception) {
00698         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00699 std::endl;
00700         std::cerr << memory_allocation_exception.what() << std::endl;
00701     }
00702     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00703
00704     #ifdef MTK_PRECISION_DOUBLE
00705     gg[0] = -1.0/2.0;
00706     #else
00707     gg[0] = -1.0f/2.0f;
00708     #endif
00709     for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00710         gg[ii] = gg[ii - 1] + mtk::kOne;
00711     }
00712
00713     #if MTK_DEBUG_LEVEL > 0
00714     std::cout << "gg0 =" << std::endl;
00715     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00716         std::cout << std::setw(12) << gg[ii];
00717     }
00718     std::cout << std::endl << std::endl;
00719     #endif
00720
00721     // Allocate 2D array to store the collection of preliminary approximations.
00722     try {
00723         prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
00724     } catch (std::bad_alloc &memory_allocation_exception) {
00725         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00726 std::endl;
00727         std::cerr << memory_allocation_exception.what() << std::endl;
00728     }
00729     memset(prem_apps_,
00730            mtk::kZero,
00731            sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00732
00733
00734     for (auto ll = 0; ll < dim_null_; ++ll) {
00735
00736         // Re-check new generator vector for every iteration except for the first.
00737         #if MTK_DEBUG_LEVEL > 0
00738         if (ll > 0) {
00739             std::cout << "gg" << ll << " =" << std::endl;
00740             for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00741                 std::cout << std::setw(12) << gg[ii];
00742             }
00743             std::cout << std::endl << std::endl;
00744         }
00745         #endif
00746
00747         bool transpose{false};
00748
00749         mtk::DenseMatrix AA_(gg,
00750                               num_bndy_coeffs_, order_accuracy_ + 1,
00751                               transpose);
00752
00753         #if MTK_DEBUG_LEVEL > 0
00754         std::cout << "AA_" << ll << " =" << std::endl;
00755         std::cout << AA_ << std::endl;
00756         #endif
00757
00758         mtk::Real *ob{};
00759
00760
00761
00762
00763

```



```

00764
00765     auto ob_ld = num_bndy_coeffs_;
00766
00767     try {
00768         ob = new mtk::Real[ob_ld];
00769     } catch (std::bad_alloc &memory_allocation_exception) {
00770         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00771             std::endl;
00772         std::cerr << memory_allocation_exception.what() << std::endl;
00773     }
00774     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00775
00776     ob[1] = mtk::kOne;
00777
00778     #if MTK_DEBUG_LEVEL > 0
00779     std::cout << "ob = " << std::endl << std::endl;
00780     for (auto ii = 0; ii < ob_ld; ++ii) {
00781         std::cout << std::setw(12) << ob[ii] << std::endl;
00782     }
00783     std::cout << std::endl;
00784     #endif
00785
00786     // However, this is an under-determined system of equations. So we can not
00787     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00788     // our LAPACKAdapter class.
00789
00790     int info_{
00791         mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
00792             ob, ob_ld)};
00793
00794     #if MTK_DEBUG_LEVEL > 0
00795     if (!info_) {
00796         std::cout << "System successfully solved!" << std::endl << std::endl;
00797     } else {
00798         std::cerr << "Error solving system! info = " << info_ << std::endl;
00799     }
00800     #endif
00801
00802     #if MTK_DEBUG_LEVEL > 0
00803     std::cout << "ob =" << std::endl;
00804     for (auto ii = 0; ii < ob_ld; ++ii) {
00805         std::cout << std::setw(12) << ob[ii] << std::endl;
00806     }
00807     std::cout << std::endl;
00808     #endif
00809
00810     // This implies a DAXPY operation. However, we must construct the arguments
00811     // for this operation.
00812
00813     // Save them into the ob_bottom array:
00814
00815     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00816
00817     try {
00818         ob_bottom = new mtk::Real[dim_null_];
00819     } catch (std::bad_alloc &memory_allocation_exception) {
00820         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00821             std::endl;
00822         std::cerr << memory_allocation_exception.what() << std::endl;
00823     }
00824     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00825
00826     for (auto ii = 0; ii < dim_null_; ++ii) {
00827         ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00828     }
00829
00830     #if MTK_DEBUG_LEVEL > 0
00831     std::cout << "ob_bottom =" << std::endl;
00832     for (auto ii = 0; ii < dim_null_; ++ii) {
00833         std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00834     }
00835     std::cout << std::endl;
00836     #endif
00837
00838     // We must computed an scaled ob, sob, using the scaled null-space in
00839     // rat_basis_null_space_.
00840     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00841     // or:
00842     ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob

```

```

00848 // thus:          Y =      a*A      *x      +      b*Y (DAXPY).
00849
00850 #if MTK_DEBUG_LEVEL > 0
00851 std::cout << "Rational basis for the null-space:" << std::endl;
00852 std::cout << rat_basis_null_space_ << std::endl;
00853 #endif
00854
00855 mtk::Real alpha{-mtk::kOne};
00856 mtk::Real beta{mtk::kOne};
00857
00858 mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00859                                ob_bottom, beta, ob);
00860
00861 #if MTK_DEBUG_LEVEL > 0
00862 std::cout << "scaled ob:" << std::endl;
00863 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00864     std::cout << std::setw(12) << ob[ii] << std::endl;
00865 }
00866 std::cout << std::endl;
00867 #endif
00868
00869 // We save the recently scaled solution, into an array containing these.
00870 // We can NOT start building the pi matrix, simply because I want that part
00871 // to be separated since its construction depends on the algorithm we want
00872 // to implement.
00873
00874 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00875     prem_apps_[ii*dim_null_ + 11] = ob[ii];
00876 }
00877
00878 // After the first iteration, simply shift the entries of the last
00879 // generator vector used:
00880 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00881     gg[ii]--;
00882 }
00883
00884 // Garbage collection for this loop:
00885 delete[] ob;
00886 ob = nullptr;
00887
00888 delete[] ob_bottom;
00889 ob_bottom = nullptr;
00890 } // End of: for (11 = 0; 11 < dim_null; 11++);
00891
00892 #if MTK_DEBUG_LEVEL > 0
00893 std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00894 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00895     for (auto jj = 0; jj < dim_null_; ++jj) {
00896         std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00897     }
00898     std::cout << std::endl;
00899 }
00900 std::cout << std::endl;
00901 #endif
00902
00903 delete[] gg;
00904 gg = nullptr;
00905
00906 return true;
00907 }
00908
00909 bool mtk::Div1D::ComputeWeights(void) {
00910
00911     // Matrix to compute the weights as in the CRSA.
00912     mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00913
00914     // Assemble the pi matrix using:
00915     // 1. The collection of scaled preliminary approximations.
00916     // 2. The collection of coefficients approximating at the interior.
00917     // 3. The scaled basis for the null-space.
00918
00919     // 1.1. Process array of scaled preliminary approximations.
00920
00921     // These are queued in scaled_solutions. Each one of these, will be a column
00922     // of the pi matrix:
00923     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00924         for (auto jj = 0; jj < dim_null_; ++jj) {
00925             pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00926                 prem_apps_[ii*dim_null_ + jj];
00927         }
00928     }

```

```

00930     }
00931
00932     // 1.2. Add columns from known stencil approximating at the interior.
00933
00934     // However, these must be padded by zeros, according to their position in the
00935     // final pi matrix:
00936     auto mm = 0;
00937     for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00938         for (auto ii = 0; ii < order_accuracy_; ++ii) {
00939             pi.data()[(ii + mm)*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00940                 coeffs_interior_[ii];
00941         }
00942         ++mm;
00943     }
00944
00945     rat_basis_null_space_.OrderColMajor();
00946
00947     #if MTK_DEBUG_LEVEL > 0
00948     std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00949     std::cout << rat_basis_null_space_ << std::endl;
00950     #endif
00951
00952     // 1.3. Add final set of columns: rational basis for null-space.
00953     for (auto jj = dim_null_ + (order_accuracy_/2 + 1); jj < num_bndy_coeffs_ - 1; ++jj) {
00954         for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00955             auto og =
00956                 (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00957             auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00958             pi.data()[de] = rat_basis_null_space_.data()[og];
00959         }
00960     }
00961
00962     #if MTK_DEBUG_LEVEL > 0
00963     std::cout << "coeffs_interior_ =" << std::endl;
00964     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00965         std::cout << std::setw(12) << coeffs_interior_[ii];
00966     }
00967     std::cout << std::endl << std::endl;
00968     #endif
00969
00970     #if MTK_DEBUG_LEVEL > 0
00971     std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00972     std::cout << pi << std::endl;
00973     #endif
00974
00975     // This imposes the mimetic condition.
00976
00977     mtk::Real *hh{}; // Right-hand side to compute weights in the C(R,B)SA.
00978
00979     try {
00980         hh = new mtk::Real[num_bndy_coeffs_];
00981     } catch (std::bad_alloc &memory_allocation_exception) {
00982         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00983             std::endl;
00984         std::cerr << memory_allocation_exception.what() << std::endl;
00985     }
00986     memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00987
00988     hh[0] = -mtk::kOne;
00989     for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00990         auto aux_xx = mtk::kZero;
00991         for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00992             aux_xx += coeffs_interior_[jj];
00993         }
00994         hh[ii] = -mtk::kOne*aux_xx;
00995     }
00996
00997     // That is, we construct a system, to solve for the weights.
00998
00999     // Once again we face the challenge of solving with LAPACK. However, for the
01000     // CRSA, this matrix PI is over-determined, since it has more rows than
01001     // unknowns. However, according to the theory, the solution to this system is
01002     // unique. We will use dgels_.
01003
01004     try {
01005         weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01006     } catch (std::bad_alloc &memory_allocation_exception) {
01007         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01008             std::endl;

```

```

01013     std::cerr << memory_allocation_exception.what() << std::endl;
01014 }
01015 memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01016
01017 int weights_ld{pi.num_cols() + 1};
01018
01019 // Preserve hh.
01020 std::copy(hh, hh + weights_ld, weights_cbs_);
01021
01022 pi.Transpose();
01023
01024 int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
pi, weights_cbs_, weights_ld)};
01025
01026 #if MTK_DEBUG_LEVEL > 0
01027 if (!info) {
01028     std::cout << "System successfully solved!" << std::endl << std::endl;
01029 } else {
01030     std::cerr << "Error solving system! info = " << info << std::endl;
01031 }
01032 #endif
01033
01034 #if MTK_DEBUG_LEVEL > 0
01035 std::cout << "hh =" << std::endl;
01036 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01037     std::cout << std::setw(11) << hh[ii] << std::endl;
01038 }
01039 std::cout << std::endl;
01040 #endif
01041
01042 // Preserve the original weights for research.
01043
01044 try {
01045     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01046 } catch (std::bad_alloc &memory_allocation_exception) {
01047     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
std::endl;
01048     std::cerr << memory_allocation_exception.what() << std::endl;
01049 }
01050
01051 memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01052
01053 std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01054
01055 #if MTK_DEBUG_LEVEL > 0
01056 std::cout << "weights_CRSA + lambda =" << std::endl;
01057 for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01058     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01059 }
01060 std::cout << std::endl;
01061 #endif
01062
01063
01064
01065 if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01066     int minrow_{std::numeric_limits<int>::infinity()};
01067
01068     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
order_accuracy_)};
01069     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01070
01071
01072
01073     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01074
01075     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01076         for (auto jj = 0; jj < dim_null_; ++jj) {
01077             phi.data()[ii*(order_accuracy_ + 1) + jj] = prem_apps_[ii*dim_null_ + jj];
01078         }
01079     }
01080
01081     int aux{}; // Auxiliary variable.
01082     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01083         for (auto ii = 0; ii < order_accuracy_; ++ii) {
01084             phi.data()[ii*(order_accuracy_ + 1) + jj] = coeffs_interior_[ii];
01085         }
01086         ++aux;
01087     }
01088
01089     for (auto jj = order_accuracy_ - 1; jj >= order_accuracy_ - dim_null_; jj--) {
01090         for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01091             phi.data()[ii*(order_accuracy_ + 1) + jj] = mtk::kZero;
01092         }
01093     }

```

```

01094     }
01095
01096     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01097         for (auto ii = 0; ii < dim_null_; ++ii) {
01098             phi.data()[ (ii + order_accuracy_ - dim_null_ + jj*order_accuracy_) ] =
01099                 -prem_apps_[ (dim_null_ - ii - 1 + jj*dim_null_) ];
01100         }
01101     }
01102
01103     for (auto ii = 0; ii < order_accuracy_/2; ++ii) {
01104         for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01105             auto swap = phi.data()[ ii*order_accuracy_+jj ];
01106             phi.data()[ ii*order_accuracy_ + jj ] =
01107                 phi.data()[ (order_accuracy_-ii)*order_accuracy_+jj ];
01108             phi.data()[ (order_accuracy_-ii)*order_accuracy_+jj ] = swap;
01109         }
01110     }
01111
01112     #if MTK_DEBUG_LEVEL > 0
01113     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01114     std::cout << phi << std::endl;
01115     #endif
01116
01117
01118
01119     mtk::Real *lamed{}; // Used to build big lambda.
01120
01121     try {
01122         lamed = new mtk::Real[dim_null_];
01123     } catch (std::bad_alloc &memory_allocation_exception) {
01124         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01125             std::endl;
01126         std::cerr << memory_allocation_exception.what() << std::endl;
01127     }
01128     memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01129
01130     for (auto ii = 0; ii < dim_null_; ++ii) {
01131         lamed[ii] = hh[ii + order_accuracy_ + 1];
01132     }
01133
01134     #if MTK_DEBUG_LEVEL > 0
01135     std::cout << "lamed =" << std::endl;
01136     for (auto ii = 0; ii < dim_null_; ++ii) {
01137         std::cout << std::setw(12) << lamed[ii] << std::endl;
01138     }
01139     std::cout << std::endl;
01140     #endif
01141
01142     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01143         mtk::Real temp = mtk::kZero;
01144         for (auto jj = 0; jj < dim_null_; ++jj) {
01145             temp = temp +
01146                 lamed[jj]*rat_basis_null_space_.data()[ jj*num_bndy_coeffs_ + ii ];
01147         }
01148         hh[ii] = hh[ii] - temp;
01149     }
01150
01151     #if MTK_DEBUG_LEVEL > 0
01152     std::cout << "big_lambda =" << std::endl;
01153     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01154         std::cout << std::setw(12) << hh[ii] << std::endl;
01155     }
01156     std::cout << std::endl;
01157     #endif
01158
01159     int copy_result{};
01160
01161     mtk::Real normerr_; // Norm of the error for the solution on each row.
01162
01163     for (auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01164         normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01165             data(),
01166                 order_accuracy_ + 1,
01167                 order_accuracy_,
01168                 order_accuracy_,
01169                 hh,
01170                 weights_cbs_,
01171                 row_,
01172                 mimetic_threshold_,
01173                 copy_result);
01174         mtk::Real aux{normerr_/norm_};
01175     }

```

```

01176
01177     #if MTK_DEBUG_LEVEL>0
01178     std::cout << "Relative norm: " << aux << " " << std::endl;
01179     std::cout << std::endl;
01180     #endif
01181
01182     if (aux < minnorm_) {
01183         minnorm_ = aux;
01184         minrow_ = row_;
01185     }
01186 }
01187
01188 #if MTK_DEBUG_LEVEL > 0
01189 std::cout << "weights_CBSA + lambda (after brute force search):" <<
01190 std::endl;
01191 for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01192     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01193 }
01194 std::cout << std::endl;
01195 #endif
01196
01198
01199 // After we know which row yields the smallest relative norm that row is
01200 // chosen to be the objective function and the result of the optimizer is
01201 // chosen to be the new weights_.
01202
01203 #if MTK_DEBUG_LEVEL > 0
01204 std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01205 minrow_ + 1 << std::endl;
01206 std::cout << std::endl;
01207 #endif
01208
01209 copy_result = 1;
01210 normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
data(),
01211                                     order_accuracy_ + 1,
01212                                     order_accuracy_,
01213                                     order_accuracy_,
01214                                     hh,
01215                                     weights_cbs_,
01216                                     minrow_,
01217                                     mimetic_threshold_,
01218                                     copy_result);
01219 mtk::Real aux_{normerr_/norm_};
01220 #if MTK_DEBUG_LEVEL > 0
01221 std::cout << "Relative norm: " << aux_ << std::endl;
01222 std::cout << std::endl;
01223 #endif
01224
01225 delete [] lamed;
01226 lamed = nullptr;
01227 }
01228
01229 delete [] hh;
01230 hh = nullptr;
01231
01232 return true;
01233 }
01234
01235 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01236
01237     #if MTK_DEBUG_LEVEL > 0
01238     std::cout << "weights_CBSA + lambda =" << std::endl;
01239     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01240         std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01241     }
01242     std::cout << std::endl;
01243     #endif
01244
01246
01247     mtk::Real *lambda{}; // Collection of bottom values from weights_.
01248
01249     try {
01250         lambda = new mtk::Real[dim_null_];
01251     } catch (std::bad_alloc &memory_allocation_exception) {
01252         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01253         std::endl;
01254         std::cerr << memory_allocation_exception.what() << std::endl;
01255     }
01256     memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01257

```

```

01258     for (auto ii = 0; ii < dim_null_; ++ii) {
01259         lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01260     }
01261
01262     #if MTK_DEBUG_LEVEL > 0
01263     std::cout << "lambda =" << std::endl;
01264     for (auto ii = 0; ii < dim_null_; ++ii) {
01265         std::cout << std::setw(12) << lambda[ii] << std::endl;
01266     }
01267     std::cout << std::endl;
01268     #endif
01269
01271
01272     mtk::Real *alpha{}; // Collection of alpha values.
01273
01274     try {
01275         alpha = new mtk::Real[dim_null_];
01276     } catch (std::bad_alloc &memory_allocation_exception) {
01277         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01278             std::endl;
01279         std::cerr << memory_allocation_exception.what() << std::endl;
01280     }
01281     memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01282
01283     for (auto ii = 0; ii < dim_null_; ++ii) {
01284         alpha[ii] = lambda[ii]/weights_cbs_[ii];
01285     }
01286
01287     #if MTK_DEBUG_LEVEL > 0
01288     std::cout << "alpha =" << std::endl;
01289     for (auto ii = 0; ii < dim_null_; ++ii) {
01290         std::cout << std::setw(12) << alpha[ii] << std::endl;
01291     }
01292     std::cout << std::endl;
01293     #endif
01294
01296
01297     try {
01298         mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01299     } catch (std::bad_alloc &memory_allocation_exception) {
01300         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01301             std::endl;
01302         std::cerr << memory_allocation_exception.what() << std::endl;
01303     }
01304     memset(mim_bndy_, mtk::kZero, sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01305
01306     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01307         for (auto jj = 0; jj < dim_null_; ++jj) {
01308             mim_bndy_[ii*dim_null_ + jj] =
01309                 prem_apps_[ii*dim_null_ + jj] +
01310                 alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01311         }
01312     }
01313
01314     #if MTK_DEBUG_LEVEL > 0
01315     std::cout << "Collection of mimetic approximations:" << std::endl;
01316     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01317         for (auto jj = 0; jj < dim_null_; ++jj) {
01318             std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01319         }
01320         std::cout << std::endl;
01321     }
01322     std::cout << std::endl;
01323     #endif
01324
01325     delete[] lambda;
01326     lambda = nullptr;
01327
01328     delete[] alpha;
01329     alpha = nullptr;
01330
01331     return true;
01332 }
01333
01334 bool mtk::Div1D::AssembleOperator(void) {
01335
01336     // The output array will have this form:
01337     // 1. The first entry of the array will contain the used order order_accuracy_.
01338     // 2. The second entry of the array will contain the collection of
01339     // approximating coefficients for the interior of the grid.
01340     // 3. IF order_accuracy_ > 2, then the third entry will contain a collection of weights.

```

```

01341 // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the collections of
01342 // approximating coefficients for the west boundary of the grid.
01343
01344 if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01345     divergence_length_ =
01346         1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
01347 } else {
01348     divergence_length_ = 1 + order_accuracy_;
01349 }
01350
01351 #if MTK_DEBUG_LEVEL > 0
01352 std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01353 #endif
01354
01355 try {
01356     divergence_ = new double[divergence_length_];
01357 } catch (std::bad_alloc &memory_allocation_exception) {
01358     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01359         std::endl;
01360     std::cerr << memory_allocation_exception.what() << std::endl;
01361 }
01362 memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01363
01364 divergence_[0] = order_accuracy_;
01365
01366 for (auto ii = 0; ii < order_accuracy_; ++ii) {
01367     divergence_[ii + 1] = coeffs_interior_[ii];
01368 }
01369
01370 if (order_accuracy_ > 2) {
01371     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01372         divergence_[1 + order_accuracy_ + ii] = weights_cbs_[ii];
01373     }
01374 }
01375
01376 if (order_accuracy_ > 2) {
01377     auto offset = (2*order_accuracy_ + 1);
01378     int mm{};
01379     for (auto ii = 0; ii < dim_null_; ++ii) {
01380         for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01381             divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01382             ++mm;
01383         }
01384     }
01385 }
01386
01387 #if MTK_DEBUG_LEVEL > 0
01388 std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01389 std::cout << std::endl;
01390 #endif
01391
01392 return true;
01393 }

```

17.63 src/mtk_div_2d.cc File Reference

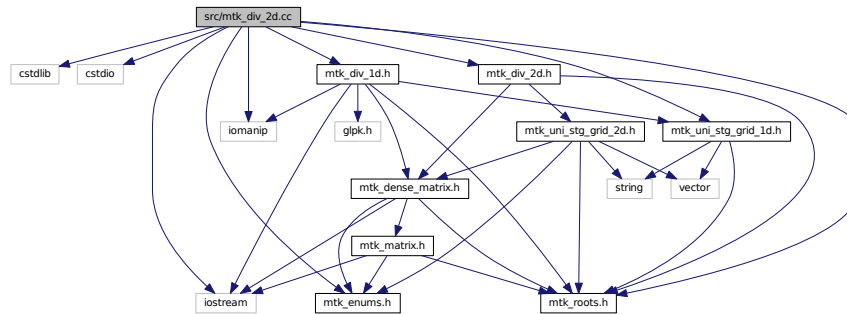
Implements the class Div2D.

```

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

```


Include dependency graph for mtk_div_2d.cc:



17.63.1 Detailed Description

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

Author

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

Definition in file [mtk_div_2d.cc](#).

17.64 mtk_div_2d.cc

```

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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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```

```

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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_enums.h"
00065 #include "mtk_uni_stg_grid_ld.h"
00066 #include "mtk_div_ld.h"
00067 #include "mtk_div_2d.h"
00068
00069 mtk::Div2D::Div2D():
00070     order_accuracy_(),
00071     mimetic_threshold_() {}
00072
00073 mtk::Div2D::Div2D(const Div2D &div):
00074     order_accuracy_(div.order_accuracy_),
00075     mimetic_threshold_(div.mimetic_threshold_) {}
00076
00077 mtk::Div2D::~Div2D() {}
00078
00079 bool mtk::Div2D::ConstructDiv2D(const
    mtk::UniStgGrid2D &grid,
                                int order_accuracy,
                                mtk::Real mimetic_threshold) {
00080
00081
00082
00083     int num_cells_x = grid.num_cells_x();
00084     int num_cells_y = grid.num_cells_y();
00085
00086     int mx = num_cells_x + 2; // Gx vertical dimension
00087     int nx = num_cells_x + 1; // Gx horizontal dimension
00088     int my = num_cells_y + 2; // Gy vertical dimension
00089     int ny = num_cells_y + 1; // Gy horizontal dimension
00090
00091     mtk::Div1D div;
00092
00093     bool info = div.ConstructDiv1D(order_accuracy, mimetic_threshold);
00094
00095     if (!info) {
00096         std::cerr << "Mimetic div could not be built." << std::endl;
00097         return info;
00098     }
00099
00100     auto west = grid.west_bndy();
00101     auto east = grid.east_bndy();
00102     auto south = grid.south_bndy();
00103     auto north = grid.east_bndy();
00104
00105     mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00106     mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00107
00108     mtk::DenseMatrix dx(div.ReturnAsDenseMatrix(grid_x));
00109     mtk::DenseMatrix dy(div.ReturnAsDenseMatrix(grid_y));
00110
00111     bool padded{true};
00112     bool transpose{false};
00113
00114     mtk::DenseMatrix ix(num_cells_x, padded, transpose);
00115     mtk::DenseMatrix iy(num_cells_y, padded, transpose);
00116
00117     mtk::DenseMatrix dxy(mtk::DenseMatrix::Kron(iy, dx));
00118     mtk::DenseMatrix dyx(mtk::DenseMatrix::Kron(dy, ix));
00119
00120     #if MTK_DEBUG_LEVEL > 0
00121     std::cout << "Gx : " << mx << "by " << nx << std::endl;
00122     std::cout << "Transpose iy : " << num_cells_y << " by " << ny << std::endl;
00123     std::cout << "Gy : " << my << "by " << ny << std::endl;

```

```

00124     std::cout << "Transpose ix : " << num_cells_x << " by " << nx << std::endl;
00125     std::cout << "Kronecker dimensions Grad 2D" <<
00126     mx*num_cells_y + my*num_cells_x << " by " << nx*ny << std::endl;
00127     #endif
00128
00129     mtk::DenseMatrix d2d(mx*my, nx*num_cells_y + ny*num_cells_x);
00130
00131     for (auto ii = 0; ii < mx*my; ii++) {
00132         for (auto jj = 0; jj < nx*num_cells_y; jj++) {
00133             d2d.SetValue(ii, jj, dxy.GetValue(ii, jj));
00134         }
00135         for (auto kk=0; kk<ny*num_cells_x; kk++) {
00136             d2d.SetValue(ii, kk + nx*num_cells_y, dyx.GetValue(ii, kk));
00137         }
00138     }
00139
00140     divergence_ = d2d;
00141
00142     return info;
00143 }
00144
00145 mtk::DenseMatrix mtk::Div2D::ReturnAsDenseMatrix() const {
00146
00147     return divergence_;
00148 }

```

17.65 src/mtk_glpk_adapter.cc File Reference

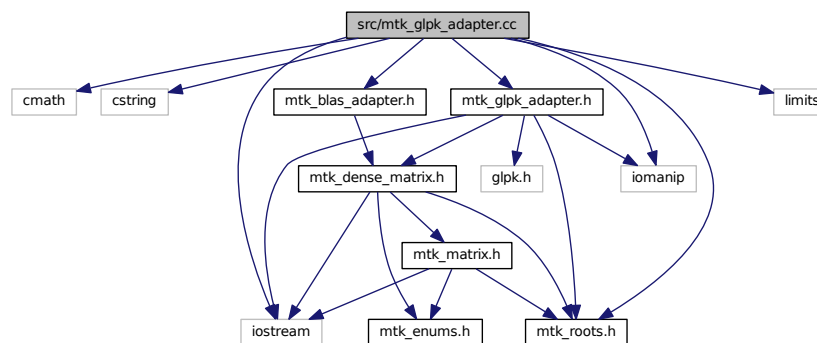
Adapter class for the GLPK API.

```

#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include "mtk_roots.h"
#include "mtk_blas_adapter.h"
#include "mtk_glpk_adapter.h"

```

Include dependency graph for mtk_glpk_adapter.cc:



17.65.1 Detailed Description

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

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

See also

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

Author

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

Definition in file [mtk_glpk_adapter.cc](#).

17.66 mtk_glpk_adapter.cc

```

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00027 and a copy of the modified files should be reported once modifications are
00028 completed, unless these modifications are made through the project's GitHub
00029 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00030 should be developed and included in any deliverable.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00061 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00062 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00063 */
00064
00065 #include <cmath>
00066 #include <cstring>
00067
00068 #include <iostream>
00069 #include <iomanip>
00070 #include <limits>
00071
00072 #include "mtk_roots.h"

```

```

00073 #include "mtk_blas_adapter.h"
00074 #include "mtk_glpk_adapter.h"
00075
00076 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
    mtk::Real *A,
    int nrows,
    int ncols,
    int kk,
    mtk::Real *hh,
    mtk::Real *qq,
    int robjective,
    mtk::Real mimetic_threshold,
    int copy) {
00086     #if MTK_DEBUG_LEVEL > 0
00087     char mps_file_name[18]; // File name for the MPS files.
00088     #endif
00089     char rname[5];          // Row name.
00090     char cname[5];          // Column name.
00091
00092     glp_prob *lp; // Linear programming problem.
00093
00094     int *ia; // Array for the problem.
00095     int *ja; // Array for the problem.
00096
00097     int problem_size; // Size of the problem.
00098     int lp_nrows;     // Number of rows.
00099     int lp_ncols;     // Number of columns.
00100     int matsize;      // Size of the matrix.
00101     int glp_index{1}; // Index of the objective function.
00102     int ii;           // Iterator.
00103     int jj;           // Iterator.
00104
00105     mtk::Real *ar;      // Array for the problem.
00106     mtk::Real *objective; // Array containing the objective function.
00107     mtk::Real *rhs;     // Array containing the rhs.
00108     mtk::Real *err;     // Array of errors.
00109
00110     mtk::Real x1;       // Norm-2 of the error.
00111
00112     #if MTK_DEBUG_LEVEL > 0
00113     mtk::Real obj_value; // Value of the objective function.
00114     #endif
00115
00116     lp_nrows = kk;
00117     lp_ncols = kk;
00118
00119     matsize = lp_nrows*lp_ncols;
00120
00124     problem_size = lp_nrows*lp_ncols + 1;
00125
00126     try {
00127         ia = new int[problem_size];
00128     } catch (std::bad_alloc &memory_allocation_exception) {
00129         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00130             std::endl;
00131         std::cerr << memory_allocation_exception.what() << std::endl;
00132     }
00133     memset(ia, 0, sizeof(ia[0])*problem_size);
00134
00135     try {
00136         ja = new int[problem_size];
00137     } catch (std::bad_alloc &memory_allocation_exception) {
00138         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00139             std::endl;
00140         std::cerr << memory_allocation_exception.what() << std::endl;
00141     }
00142     memset(ja, 0, sizeof(ja[0])*problem_size);
00143
00144     try {
00145         ar = new mtk::Real[problem_size];
00146     } catch (std::bad_alloc &memory_allocation_exception) {
00147         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00148             std::endl;
00149         std::cerr << memory_allocation_exception.what() << std::endl;
00150     }
00151     memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00152
00153     try {
00154         objective = new mtk::Real[lp_ncols + 1];

```

```

00155 } catch (std::bad_alloc &memory_allocation_exception) {
00156     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00157     std::endl;
00158     std::cerr << memory_allocation_exception.what() << std::endl;
00159 }
00160 memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00161
00162 try {
00163     rhs = new mtk::Real[lp_nrows + 1];
00164 } catch (std::bad_alloc &memory_allocation_exception) {
00165     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00166     std::endl;
00167     std::cerr << memory_allocation_exception.what() << std::endl;
00168 }
00169 memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00170
00171 try {
00172     err = new mtk::Real[lp_nrows];
00173 } catch (std::bad_alloc &memory_allocation_exception) {
00174     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00175     std::endl;
00176     std::cerr << memory_allocation_exception.what() << std::endl;
00177 }
00178 memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00179
00180 #if MTK_DEBUG_LEVEL > 0
00181 std::cout << "Problem size: " << problem_size << std::endl;
00182 std::cout << "lp_nrows = " << lp_nrows << std::endl;
00183 std::cout << "lp_ncols = " << lp_ncols << std::endl;
00184 std::cout << std::endl;
00185 #endif
00186
00187 lp = glp_create_prob();
00188
00189 glp_set_prob_name (lp, "mtk:GLPKAdapter::Simplex");
00190
00191 glp_set_obj_dir (lp, GLP_MIN);
00192
00193
00194
00195 glp_add_rows(lp, lp_nrows);
00196
00197 for (ii = 1; ii <= lp_nrows; ++ii) {
00198     sprintf(rname, "R%02d",ii);
00199     glp_set_row_name(lp, ii, rname);
00200 }
00201
00202 glp_add_cols(lp, lp_ncols);
00203
00204 for (ii = 1; ii <= lp_ncols; ++ii) {
00205     sprintf(cname, "Q%02d",ii);
00206     glp_set_col_name (lp, ii, cname);
00207 }
00208
00209
00210
00211 #if MTK_DEBUG_LEVEL>0
00212 std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00213 #endif
00214 for (jj = 0; jj < kk; ++jj) {
00215     objective[glp_index] = A[jj + robjective * ncols];
00216     glp_index++;
00217 }
00218 #if MTK_DEBUG_LEVEL >0
00219 std::cout << std::endl;
00220 #endif
00221
00222
00223
00224 glp_index = 1;
00225 rhs[0] = mtk::kZero;
00226 for (ii = 0; ii <= lp_nrows; ++ii) {
00227     if (ii != robjective) {
00228         rhs[glp_index] = hh[ii];
00229         glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00230         glp_index++;
00231     }
00232 }
00233
00234 #if MTK_DEBUG_LEVEL > 0
00235 std::cout << "rhs =" << std::endl;
00236 for (auto ii = 0; ii < lp_nrows; ++ii) {
00237     std::cout << std::setw(15) << rhs[ii] << std::endl;
00238 }

```

```

00239     std::cout << std::endl;
00240     #endif
00241
00242
00243
00244     for (ii = 1; ii <= lp_ncols; ++ii) {
00245         glp_set_obj_coef (lp, ii, objective[ii]);
00246     }
00247
00248
00249
00250     for (ii = 1; ii <= lp_ncols; ++ii) {
00251         glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00252     }
00253
00254
00255
00256     glp_index = 1;
00257     for (ii = 0; ii <= kk; ++ii) {
00258         for (jj = 0; jj < kk; ++jj) {
00259             if (ii != robjective) {
00260                 ar[glp_index] = A[jj + ii * ncols];
00261                 glp_index++;
00262             }
00263         }
00264     }
00265
00266     glp_index = 0;
00267
00268     for (ii = 1; ii < problem_size; ++ii) {
00269         if ((ii - 1) % lp_ncols == 0) {
00270             glp_index++;
00271         }
00272         ia[ii] = glp_index;
00273         ja[ii] = (ii - 1) % lp_ncols + 1;
00274     }
00275
00276     glp_load_matrix (lp, matsize, ia, ja, ar);
00277
00278     #if MTK_DEBUG_LEVEL > 0
00279     sprintf(mps_file_name, "LP_MPS_row_%02d.mps", robjective);
00280     glp_write_mps(lp, GLP_MPS_FILE, nullptr, mps_file_name);
00281     #endif
00282
00283
00284
00285     glp_simplex (lp, nullptr);
00286
00287     // Check status of the solution.
00288
00289     if (glp_get_status(lp) == GLP_OPT) {
00290
00291         for(ii = 1; ii <= lp_ncols; ++ii) {
00292             err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp,ii);
00293         }
00294
00295         #if MTK_DEBUG_LEVEL > 0
00296         obj_value = glp_get_obj_val (lp);
00297         std::cout << std::setw(12) << "CBS" << std::setw(12) << "CRS" << std::endl;
00298         for (ii = 0; ii < lp_ncols; ++ii) {
00299             std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00300                 glp_get_col_prim(lp,ii + 1) << std::setw(12) << qq[ii] << std::endl;
00301         }
00302         std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00303             obj_value << std::endl;
00304         #endif
00305
00306         if (copy) {
00307             for(ii = 0; ii < lp_ncols; ++ii) {
00308                 qq[ii] = glp_get_col_prim(lp,ii + 1);
00309             }
00310             // Preserve the bottom values of qq.
00311         }
00312
00313         x1 = mtk::BLASAdapter::RealNRM2(err,lp_ncols);
00314
00315     } else {
00316         x1 = std::numeric_limits<mtk::Real>::infinity();
00317     }
00318
00319     glp_delete_prob (lp);
00320     glp_free_env ();
00321
00322     delete [] ia;
00323     delete [] ja;

```

```

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

```

17.67 src/mtk_grad_1d.cc File Reference

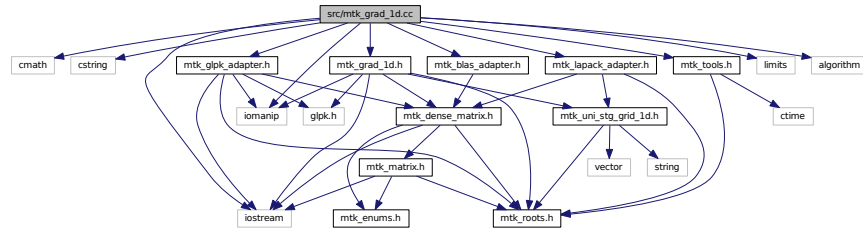
Implements the class Grad1D.

```

#include <cmath>
#include <cstring>
#include <iostream>
#include <iomanip>
#include <limits>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_lapack_adapter.h"
#include "mtk_glpk_adapter.h"
#include "mtk_grad_1d.h"

```

Include dependency graph for mtk_grad_1d.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

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

17.67.1 Detailed Description

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

Author

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

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

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

Definition in file `mtk_grad_1d.cc`.

17.68 mtk_grad_1d.cc

```

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00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cmath>
00062 #include <cstring>
00063
00064 #include <iostream>
00065 #include <iomanip>
00066 #include <limits>
00067 #include <algorithm>
00068
00069 #include "mtk_tools.h"
00070
00071 #include "mtk_blas_adapter.h"
00072 #include "mtk_lapack_adapter.h"
00073 #include "mtk_glpk_adapter.h"
00074

```

```

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

```

```

00159   mimetic_threshold_(grad.mimetic_threshold_) {}
00160
00161 mtk::Grad1D::~Grad1D() {
00162
00163     delete[] coeffs_interior_;
00164     coeffs_interior_ = nullptr;
00165
00166     delete[] prem_apps_;
00167     prem_apps_ = nullptr;
00168
00169     delete[] weights_crs_;
00170     weights_crs_ = nullptr;
00171
00172     delete[] weights_cbs_;
00173     weights_cbs_ = nullptr;
00174
00175     delete[] mim_bndy_;
00176     mim_bndy_ = nullptr;
00177
00178     delete[] gradient_;
00179     gradient_ = nullptr;
00180 }
00181
00182 bool mtk::Grad1D::ConstructGrad1D(int order_accuracy,
00183   Real mimetic_threshold) {
00184
00185     #if MTK_DEBUG_LEVEL > 0
00186     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00187     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00188     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00189       __FILE__, __LINE__, __func__);
00189
00190     if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00191         std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00192     }
00193
00194     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00195     std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00196     #endif
00197
00198     order_accuracy_ = order_accuracy;
00199     mimetic_threshold_ = mimetic_threshold;
00200
00202
00203     bool abort_construction = ComputeStencilInteriorGrid();
00204
00205     #if MTK_DEBUG_LEVEL > 0
00206     if (!abort_construction) {
00207         std::cerr << "Could NOT complete stage 1." << std::endl;
00208         std::cerr << "Exiting..." << std::endl;
00209         return false;
00210     }
00211     #endif
00212
00213     // At this point, we already have the values for the interior stencil stored
00214     // in the coeffs_interior_ array.
00215
00216     dim_null_ = order_accuracy_/2 - 1;
00217
00218     num_bndy_approxs_ = dim_null_ + 1;
00219
00220     #ifdef MTK_PRECISION_DOUBLE
00221     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00222     #else
00223     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00224     #endif
00225
00227
00228     // For this we will follow recommendations given in:
00229     //
00230     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00231     //
00232     // We will compute the QR Factorization of the transpose, as in the
00233     // following (MATLAB) pseudo-code:
00234     //
00235     // [Q,R] = qr(V'); % Full QR as defined in
00236     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00237     //
00238     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00239     //
00240     // However, given the nature of the Vandermonde matrices we've just

```

```

00241 // computed, they all posses the same null-space. Therefore, we impose the
00242 // convention of computing the null-space of the first Vandermonde matrix
00243 // (west boundary).
00244
00245 // In the case of the gradient, the first Vandermonde system has a unique
00246 // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00247 // matrix used to assemble said system, will have an empty null-space.
00248
00249 // Therefore, we only compute a rational basis for the case of order higher
00250 // than second.
00251
00252 if (dim_null_ > 0) {
00253     abort_construction = ComputeRationalBasisNullSpace();
00254
00255     #if MTK_DEBUG_LEVEL > 0
00256     if (!abort_construction) {
00257         std::cerr << "Could NOT complete stage 2.1." << std::endl;
00258         std::cerr << "Exiting..." << std::endl;
00259         return false;
00260     }
00261     #endif
00262 }
00263
00264
00266 abort_construction = ComputePreliminaryApproximations();
00267
00268 #if MTK_DEBUG_LEVEL > 0
00269 if (!abort_construction) {
00270     std::cerr << "Could NOT complete stage 2.2." << std::endl;
00271     std::cerr << "Exiting..." << std::endl;
00272     return false;
00273 }
00274 #endif
00275
00276 abort_construction = ComputeWeights();
00277
00278 #if MTK_DEBUG_LEVEL > 0
00279 if (!abort_construction) {
00280     std::cerr << "Could NOT complete stage 2.3." << std::endl;
00281     std::cerr << "Exiting..." << std::endl;
00282     return false;
00283 }
00284 #endif
00285
00286
00288 if (dim_null_ > 0) {
00289     abort_construction = ComputeStencilBoundaryGrid();
00290
00291     #if MTK_DEBUG_LEVEL > 0
00292     if (!abort_construction) {
00293         std::cerr << "Could NOT complete stage 2.4." << std::endl;
00294         std::cerr << "Exiting..." << std::endl;
00295         return false;
00296     }
00297     #endif
00298 }
00299
00300
00302 // Once we have the following three collections of data:
00303 // (a) the coefficients for the interior,
00304 // (b) the coefficients for the boundary (if it applies),
00305 // (c) and the weights (if it applies),
00306 // we will store everything in the output array:
00307
00308 abort_construction = AssembleOperator();
00309
00310 #if MTK_DEBUG_LEVEL > 0
00311 if (!abort_construction) {
00312     std::cerr << "Could NOT complete stage 3." << std::endl;
00313     std::cerr << "Exiting..." << std::endl;
00314     return false;
00315 }
00316 #endif
00317
00318 return true;
00319 }
00320
00321 int mtk::Grad1D::num_bndy_coeffs() const {

```

```

00326
00327     return num_bndy_coeffs_;
00328 }
00329
00330 mtk::Real *mtk::Grad1D::coeffs_interior() const {
00331
00332     return coeffs_interior_;
00333 }
00334
00335 mtk::Real *mtk::Grad1D::weights_crs() const {
00336
00337     return weights_crs_;
00338 }
00339
00340 mtk::Real *mtk::Grad1D::weights_cbs() const {
00341
00342     return weights_cbs_;
00343 }
00344
00345 mtk::DenseMatrix mtk::Grad1D::mim_bndy() const {
00346
00347     mtk::DenseMatrix xx(dim_null_, 3*order_accuracy_/2);
00348
00349     auto counter = 0;
00350     for (auto ii = 0; ii < dim_null_; ++ii) {
00351         for (auto jj = 0; jj < 3*order_accuracy_/2; ++jj) {
00352             xx.SetValue(ii, jj, gradient_[2*order_accuracy_ + 1 + counter]);
00353             counter++;
00354         }
00355     }
00356     return xx;
00357 }
00358
00359 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
00360     mtk::Real west,
00361                                     mtk::Real east,
00362                                     int num_cells_x) const {
00363
00364     int nn{num_cells_x}; // Number of cells on the grid.
00365
00366     #if MTK_DEBUG_LEVEL > 0
00367     mtk::Tools::Prevent(east < west, __FILE__, __LINE__, __func__);
00368     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00369     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00370     #endif
00371
00372     mtk::Real delta_x = (east - west)/((mtk::Real) num_cells_x);
00373
00374     mtk::Real inv_delta_x{mtk::kOne/delta_x};
00375
00376     int gg_num_rows = nn + 1;
00377     int gg_num_cols = nn + 2;
00378     int elements_per_row = num_bndy_coeffs_;
00379     int num_extra_rows = order_accuracy_/2;
00380
00381     // Output matrix featuring sizes for gradient operators.
00382     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00383
00384     auto ee_index = 0;
00385     for (auto ii = 0; ii < num_extra_rows; ii++) {
00386         auto cc = 0;
00387         for (auto jj = 0; jj < gg_num_cols; jj++) {
00388             if (cc >= elements_per_row) {
00389                 out.SetValue(ii, jj, mtk::kZero);
00390             } else {
00391                 out.SetValue(ii, jj,
00392                             gradient_[2*order_accuracy_ + 1 + ee_index++] * inv_delta_x);
00393                 cc++;
00394             }
00395         }
00396     }
00397
00398 }
00399
00400
00401
00402     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00403         auto jj = ii - num_extra_rows + 1;
00404         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00405             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00406         }
00407     }

```

```

00408
00410
00411 ee_index = 0;
00412 for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00413     auto cc = 0;
00414     for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00415         if(cc >= elements_per_row) {
00416             out.SetValue(ii,jj,mtk::kZero);
00417         } else {
00418             out.SetValue(ii,jj,
00419                 -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00420             cc++;
00421         }
00422     }
00423 }
00424
00425 return out;
00426 }
00427
00428 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(
00429     const UniStgGrid1D &grid) const {
00430
00431     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00432
00433     #if MTK_DEBUG_LEVEL > 0
00434     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00435     mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00436     #endif
00437
00438     mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00439
00440     int gg_num_rows = nn + 1;
00441     int gg_num_cols = nn + 2;
00442     int elements_per_row = num_bndy_coeffs_;
00443     int num_extra_rows = order_accuracy_/2;
00444
00445     // Output matrix featuring sizes for gradient operators.
00446     mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00447
00448
00449
00450     auto ee_index = 0;
00451     for (auto ii = 0; ii < num_extra_rows; ii++) {
00452         auto cc = 0;
00453         for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00454             if(cc >= elements_per_row) {
00455                 out.SetValue(ii, jj, mtk::kZero);
00456             } else {
00457                 out.SetValue(ii,jj,
00458                     gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00459                 cc++;
00460             }
00461         }
00462     }
00463
00464     for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00465         auto jj = ii - num_extra_rows + 1;
00466         for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00467             out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00470         }
00471     }
00472
00473
00474
00475     ee_index = 0;
00476     for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00477         auto cc = 0;
00478         for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00479             if(cc >= elements_per_row) {
00480                 out.SetValue(ii,jj,mtk::kZero);
00481             } else {
00482                 out.SetValue(ii,jj,
00483                     -gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00484                 cc++;
00485             }
00486         }
00487     }
00488
00489     return out;
00490 }
00491
00492 mtk::DenseMatrix mtk::Grad1D::ReturnAsDimensionlessDenseMatrix

```

```

(
00493   int num_cells_x) const {
00494
00495   int nn{num_cells_x}; // Number of cells on the grid.
00496
00497   #if MTK_DEBUG_LEVEL > 0
00498   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00499   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00500   #endif
00501
00502   int gg_num_rows = nn + 1;
00503   int gg_num_cols = nn + 2;
00504   int elements_per_row = num_bndy_coeffs_;
00505   int num_extra_rows = order_accuracy_/2;
00506
00507   // Output matrix featuring sizes for gradient operators.
00508   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00509
00510   auto ee_index = 0;
00511   for (auto ii = 0; ii < num_extra_rows; ii++) {
00512       auto cc = 0;
00513       for (auto jj = 0; jj < gg_num_cols; jj++) {
00514           if (cc >= elements_per_row) {
00515               out.SetValue(ii, jj, mtk::kZero);
00516           } else {
00517               out.SetValue(ii, jj,
00518                           gradient_[2*order_accuracy_ + 1 + ee_index++]);
00519               cc++;
00520           }
00521       }
00522   }
00523
00524   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00525       auto jj = ii - num_extra_rows + 1;
00526       for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00527           out.SetValue(ii, jj, coeffs_interior_[cc]);
00528       }
00529   }
00530
00531   ee_index = 0;
00532   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00533       auto cc = 0;
00534       for (auto jj = gg_num_cols - 1; jj >= 0; jj--) {
00535           if (cc >= elements_per_row) {
00536               out.SetValue(ii, jj, mtk::kZero);
00537           } else {
00538               out.SetValue(ii, jj,
00539                           -gradient_[2*order_accuracy_ + 1 + ee_index++]);
00540               cc++;
00541           }
00542       }
00543   }
00544
00545   return out;
00546 }
00547
00548 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00549
00550   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00551
00552   try {
00553       pp = new mtk::Real[order_accuracy_];
00554   } catch (std::bad_alloc &memory_allocation_exception) {
00555       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00556       std::endl;
00557       std::cerr << memory_allocation_exception.what() << std::endl;
00558   }
00559   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00560
00561   #ifdef MTK_PRECISION_DOUBLE
00562   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00563   #else
00564   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00565   #endif
00566
00567   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00568       pp[ii] = pp[ii - 1] + mtk::kOne;
00569   }

```

```

00577     }
00578
00579     #if MTK_DEBUG_LEVEL > 0
00580     std::cout << "pp =" << std::endl;
00581     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00582         std::cout << std::setw(12) << pp[ii];
00583     }
00584     std::cout << std::endl << std::endl;
00585     #endif
00586
00587     bool transpose{false};
00588
00589     mtk::DenseMatrix vander_matrix(pp, order_accuracy_, order_accuracy_, transpose);
00590
00591     #if MTK_DEBUG_LEVEL > 0
00592     std::cout << "vander_matrix = " << std::endl;
00593     std::cout << vander_matrix << std::endl << std::endl;
00594     #endif
00595
00596     try {
00597         coeffs_interior_ = new mtk::Real[order_accuracy_];
00598     } catch (std::bad_alloc &memory_allocation_exception) {
00599         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00600             std::endl;
00601         std::cerr << memory_allocation_exception.what() << std::endl;
00602     }
00603     memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00604
00605     coeffs_interior_[1] = mtk::kOne;
00606
00607     #if MTK_DEBUG_LEVEL > 0
00608     std::cout << "oo =" << std::endl;
00609     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00610         std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00611     }
00612     std::cout << std::endl;
00613     #endif
00614
00615     int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00616         coeffs_interior_)};
00617
00618     #if MTK_DEBUG_LEVEL > 0
00619     if (!info) {
00620         std::cout << "System solved! Interior stencil attained!" << std::endl;
00621         std::cout << std::endl;
00622     }
00623     else {
00624         std::cerr << "Something wrong solving system! info = " << info << std::endl;
00625         std::cerr << "Exiting..." << std::endl;
00626         return false;
00627     }
00628     #endif
00629
00630     #if MTK_DEBUG_LEVEL > 0
00631     std::cout << "coeffs_interior_ =" << std::endl;
00632     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00633         std::cout << std::setw(12) << coeffs_interior_[ii];
00634     }
00635     std::cout << std::endl << std::endl;
00636     #endif
00637
00638     delete [] pp;
00639     pp = nullptr;
00640
00641     return true;
00642 }
00643
00644 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00645
00646     mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00647
00648     try {
00649         gg = new mtk::Real[num_bndy_coeffs_];
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;

```



```

00662     }
00663     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00664
00665     #ifdef MTK_PRECISION_DOUBLE
00666     gg[1] = 1.0/2.0;
00667     #else
00668     gg[1] = 1.0f/2.0f;
00669     #endif
00670     for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00671         gg[ii] = gg[ii - 1] + mtk::kOne;
00672     }
00673
00674     #if MTK_DEBUG_LEVEL > 0
00675     std::cout << "gg =" << std::endl;
00676     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00677         std::cout << std::setw(12) << gg[ii];
00678     }
00679     std::cout << std::endl << std::endl;
00680     #endif
00681
00682     bool tran{true}; // Should I transpose the Vandermonde matrix.
00683
00684     mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy + 1, tran);
00685
00686     #if MTK_DEBUG_LEVEL > 0
00687     std::cout << "aa_west_t =" << std::endl;
00688     std::cout << aa_west_t << std::endl;
00689     #endif
00690
00691     mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
00692     (aa_west_t));
00693
00694     #if MTK_DEBUG_LEVEL > 0
00695     std::cout << "qq_t =" << std::endl;
00696     std::cout << qq_t << std::endl;
00697     #endif
00698
00699     int kk_num_rows{num_bndy_coeffs_};
00700     int kk_num_cols{dim_null_};
00701
00702     mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00703
00704     // In the case of the gradient, even though we must solve for a null-space
00705     // of dimension 2, we must only extract ONE basis for the kernel.
00706     // We perform this extraction here:
00707
00708     int aux_{kk_num_rows - kk_num_cols};
00709     for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00710         aux_--;
00711         for (auto jj = 0; jj < kk_num_rows; jj++) {
00712             kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00713             qq_t.data()[ii*num_bndy_coeffs_ + jj];
00714         }
00715     }
00716
00717     #if MTK_DEBUG_LEVEL > 0
00718     std::cout << "kk =" << std::endl;
00719     std::cout << kk << std::endl;
00720     std::cout << "kk.num_rows() =" << kk.num_rows() << std::endl;
00721     std::cout << "kk.num_cols() =" << kk.num_cols() << std::endl;
00722     #endif
00723
00724     // Scale thus requesting that the last entries of the attained basis for the
00725     // null-space, adopt the pattern we require.
00726     // Essentially we will implement the following MATLAB pseudo-code:
00727     //   scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00728     //   SK = kk*scalers
00729     // where SK is the scaled null-space.
00730
00731     // In this point, we almost have all the data we need correctly allocated
00732     // in memory. We will create the matrix iden_, and elements we wish to scale in
00733     // the kk array. Using the concept of the leading dimension, we could just
00734     // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00735     // GET how does it work. So I will just create a matrix with the content of
00736     // this array that we need, solve for the scalers and then scale the
00737     // whole kk:

```

```

00746
00747 // We will then create memory for that sub-matrix of kk (subk).
00748
00749 mtk::DenseMatrix subk(dim_null_, dim_null_);
00750
00751 auto zz = 0;
00752 for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00753     for (auto jj = 0; jj < dim_null_; jj++) {
00754         subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00755     }
00756     zz++;
00757 }
00758
00759 #if MTK_DEBUG_LEVEL > 0
00760 std::cout << "subk =" << std::endl;
00761 std::cout << subk << std::endl;
00762 #endif
00763
00764 subk.Transpose();
00765
00766 #if MTK_DEBUG_LEVEL > 0
00767 std::cout << "subk_t =" << std::endl;
00768 std::cout << subk << std::endl;
00769 #endif
00770
00771 bool padded{false};
00772 tran = false;
00773
00774 mtk::DenseMatrix iden(dim_null_, padded, tran);
00775
00776 #if MTK_DEBUG_LEVEL > 0
00777 std::cout << "iden =" << std::endl;
00778 std::cout << iden << std::endl;
00779 #endif
00780
00781 // Solve the system to compute the scalars.
00782 // An example of the system to solve, for k = 8, is:
00783 //
00784 // subk*scalars = iden or
00785 //
00786 // | 0.386018 -0.0339244 -0.129478 |           | 1 0 0 |
00787 // | -0.119774 0.0199423 0.0558632 |*scalars = | 0 1 0 |
00788 // | 0.0155708 -0.00349546 -0.00853182 |       | 0 0 1 |
00789 //
00790 // Notice this is a nrhs = 3 system.
00791 // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalars... they
00792 // will be stored in the created identity matrix.
00793 // Let us first transpose subk (because of LAPACK):
00794
00795 int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00796
00797 #if MTK_DEBUG_LEVEL > 0
00798 if (!info) {
00799     std::cout << "System successfully solved!" <<
00800         std::endl;
00801 } else {
00802     std::cerr << "Something went wrong solving system! info = " << info <<
00803         std::endl;
00804     std::cerr << "Exiting..." << std::endl;
00805     return false;
00806 }
00807 std::cout << std::endl;
00808 #endif
00809
00810 #if MTK_DEBUG_LEVEL > 0
00811 std::cout << "Computed scalars:" << std::endl;
00812 std::cout << iden << std::endl;
00813 #endif
00814
00815 // Multiply the two matrices to attain a scaled basis for null-space.
00816
00817 rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00818
00819 #if MTK_DEBUG_LEVEL > 0
00820 std::cout << "Rational basis for the null-space:" << std::endl;
00821 std::cout << rat_basis_null_space_ << std::endl;
00822 #endif
00823
00824 // At this point, we have a rational basis for the null-space, with the
00825 // pattern we need! :)
00826

```

```

00827     delete [] gg;
00828     gg = nullptr;
00829
00830     return true;
00831 }
00832
00833 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00834
00835     mtk::Real *gg{}; // Generator vector for the first approximation.
00836
00837     try {
00838         gg = new mtk::Real[num_bndy_coeffs_];
00839     } catch (std::bad_alloc &memory_allocation_exception) {
00840         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00841             std::endl;
00842         std::cerr << memory_allocation_exception.what() << std::endl;
00843     }
00844     memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00845
00846     #ifdef MTK_PRECISION_DOUBLE
00847         gg[1] = 1.0/2.0;
00848     #else
00849         gg[1] = 1.0f/2.0f;
00850     #endif
00851     for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00852         gg[ii] = gg[ii - 1] + mtk::kOne;
00853     }
00854
00855     #if MTK_DEBUG_LEVEL > 0
00856     std::cout << "gg0 =" << std::endl;
00857     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00858         std::cout << std::setw(12) << gg[ii];
00859     }
00860     std::cout << std::endl << std::endl;
00861     #endif
00862
00863     // Allocate 2D array to store the collection of preliminary approximations.
00864     try {
00865         prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00866     } catch (std::bad_alloc &memory_allocation_exception) {
00867         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00868             std::endl;
00869         std::cerr << memory_allocation_exception.what() << std::endl;
00870     }
00871     memset(prem_apps_,
00872         mtk::kZero,
00873         sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00874
00875     for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00876
00877         // Re-check new generator vector for every iteration except for the first.
00878         #if MTK_DEBUG_LEVEL > 0
00879         if (ll > 0) {
00880             std::cout << "gg" << ll << " =" << std::endl;
00881             for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00882                 std::cout << std::setw(12) << gg[ii];
00883             }
00884             std::cout << std::endl << std::endl;
00885         }
00886         #endif
00887
00888         bool transpose{false};
00889
00890         mtk::DenseMatrix aa(gg,
00891             num_bndy_coeffs_, order_accuracy_ + 1,
00892             transpose);
00893
00894         #if MTK_DEBUG_LEVEL > 0
00895         std::cout << "aa_" << ll << " =" << std::endl;
00896         std::cout << aa << std::endl;
00897         #endif
00898
00899         mtk::Real *ob{};
00900
00901         auto ob_ld = num_bndy_coeffs_;
00902
00903         try {

```

```

00912     ob = new mtk::Real[ob_ld];
00913 } catch (std::bad_alloc &memory_allocation_exception) {
00914     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00915         std::endl;
00916     std::cerr << memory_allocation_exception.what() << std::endl;
00917 }
00918 memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00919
00920 ob[1] = mtk::kOne;
00921
00922 #if MTK_DEBUG_LEVEL > 0
00923 std::cout << "ob = " << std::endl << std::endl;
00924 for (auto ii = 0; ii < ob_ld; ++ii) {
00925     std::cout << std::setw(12) << ob[ii] << std::endl;
00926 }
00927 std::cout << std::endl;
00928 #endif
00929
00931 // However, this is an under-determined system of equations. So we can not
00932 // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00933 // our LAPACKAdapter class.
00934
00935 int info_{
00937     mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
, ob_ld)};
00938
00939 #if MTK_DEBUG_LEVEL > 0
00940 if (!info_) {
00941     std::cout << "System successfully solved!" << std::endl << std::endl;
00942 } else {
00943     std::cerr << "Error solving system! info = " << info_ << std::endl;
00944 }
00945 #endif
00946
00947 #if MTK_DEBUG_LEVEL > 0
00948 std::cout << "ob =" << std::endl;
00949 for (auto ii = 0; ii < ob_ld; ++ii) {
00950     std::cout << std::setw(12) << ob[ii] << std::endl;
00951 }
00952 std::cout << std::endl;
00953 #endif
00954
00957 // This implies a DAXPY operation. However, we must construct the arguments
00958 // for this operation.
00959
00961 // Save them into the ob_bottom array:
00962
00963 Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00964
00965 try {
00966     ob_bottom = new mtk::Real[dim_null_];
00967 } catch (std::bad_alloc &memory_allocation_exception) {
00968     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00969         std::endl;
00970     std::cerr << memory_allocation_exception.what() << std::endl;
00971 }
00972 memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00973
00974 for (auto ii = 0; ii < dim_null_; ++ii) {
00975     ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00976 }
00977
00978 #if MTK_DEBUG_LEVEL > 0
00979 std::cout << "ob_bottom =" << std::endl;
00980 for (auto ii = 0; ii < dim_null_; ++ii) {
00981     std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00982 }
00983 std::cout << std::endl;
00984 #endif
00985
00987
00988 // We must computed an scaled ob, sob, using the scaled null-space in
00989 // rat_basis_null_space_.
00990 // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00991 // or:
00992 // thus:
00993 //      Y =      a*A      *x      +      b*Y (DAXPY).
00994
00995 #if MTK_DEBUG_LEVEL > 0
00996 std::cout << "Rational basis for the null-space:" << std::endl;

```

```

00996     std::cout << rat_basis_null_space_ << std::endl;
00997     #endif
00998
00999     mtk::Real alpha{-mtk::kOne};
01000     mtk::Real beta{mtk::kOne};
01001
01002     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
01003                                   ob_bottom, beta, ob);
01004
01005     #if MTK_DEBUG_LEVEL > 0
01006     std::cout << "scaled ob:" << std::endl;
01007     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01008         std::cout << std::setw(12) << ob[ii] << std::endl;
01009     }
01010     std::cout << std::endl;
01011     #endif
01012
01013     // We save the recently scaled solution, into an array containing these.
01014     // We can NOT start building the pi matrix, simply because I want that part
01015     // to be separated since its construction depends on the algorithm we want
01016     // to implement.
01017
01018     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01019         prem_apps_[ii*num_bndy_approxs_ + 11] = ob[ii];
01020     }
01021
01022     // After the first iteration, simply shift the entries of the last
01023     // generator vector used:
01024     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01025         gg[ii]--;
01026     }
01027
01028     // Garbage collection for this loop:
01029     delete[] ob;
01030     ob = nullptr;
01031
01032     delete[] ob_bottom;
01033     ob_bottom = nullptr;
01034 } // End of: for (ll = 0; ll < dim_null; ll++);
01035
01036 #if MTK_DEBUG_LEVEL > 0
01037 std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
01038 for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01039     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01040         std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
01041     }
01042     std::cout << std::endl;
01043 }
01044 std::cout << std::endl;
01045 #endif
01046
01047 delete[] gg;
01048 gg = nullptr;
01049
01050 return true;
01051 }
01052
01053 bool mtk::Grad1D::ComputeWeights() {
01054
01055     // Matrix to compute the weights as in the CRSA.
01056     mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
01057
01058     // Assemble the pi matrix using:
01059     // 1. The collection of scaled preliminary approximations.
01060     // 2. The collection of coefficients approximating at the interior.
01061     // 3. The scaled basis for the null-space.
01062
01063     // 1.1. Process array of scaled preliminary approximations.
01064
01065     // These are queued in scaled_solutions. Each one of these, will be a column
01066     // of the pi matrix:
01067     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01068         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01069             pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
01070                 prem_apps_[ii*num_bndy_approxs_ + jj];
01071         }
01072     }
01073
01074     // 1.2. Add columns from known stencil approximating at the interior.
01075
01076
01077

```

```

01078 // However, these must be padded by zeros, according to their position in the
01079 // final pi matrix:
01080 auto mm = 1;
01081 for (auto jj = num_bndy_apprxs_; jj < order_accuracy_; ++jj) {
01082     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01083         auto de = (ii + mm)*(2*(num_bndy_apprxs_ - 1) +
01084             (order_accuracy_/2 + 1)) + jj;
01085         pi.data()[de] = coeffs_interior_[ii];
01086     }
01087     ++mm;
01088 }
01089
01090 rat_basis_null_space_.OrderColMajor();
01091
01092 #if MTK_DEBUG_LEVEL > 0
01093 std::cout << "Rational basis for the null-space (col. major):" << std::endl;
01094 std::cout << rat_basis_null_space_ << std::endl;
01095 #endif
01096
01097 // 1.3. Add final set of columns: rational basis for null-space.
01098
01099 for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
01100     jj < num_bndy_coeffs_ - 1; ++jj) {
01101     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01102         auto og =
01103             (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
01104         auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
01105         pi.data()[de] = rat_basis_null_space_.data()[og];
01106     }
01107 }
01108
01109 #if MTK_DEBUG_LEVEL > 0
01110 std::cout << "coeffs_interior_ =" << std::endl;
01111 for (auto ii = 0; ii < order_accuracy_; ++ii) {
01112     std::cout << std::setw(12) << coeffs_interior_[ii];
01113 }
01114 std::cout << std::endl << std::endl;
01115 #endif
01116
01117 #if MTK_DEBUG_LEVEL > 0
01118 std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
01119 std::cout << pi << std::endl;
01120 #endif
01121
01122 // This imposes the mimetic condition.
01123
01124 mtk::Real *hh{}; // Right-hand side to compute weights in the C{R,B}SA.
01125
01126 try {
01127     hh = new mtk::Real[num_bndy_coeffs_];
01128 } catch (std::bad_alloc &memory_allocation_exception) {
01129     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01130         std::endl;
01131     std::cerr << memory_allocation_exception.what() << std::endl;
01132 }
01133 memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
01134
01135 hh[0] = -mtk::kOne;
01136 for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
01137     auto aux_xx = mtk::kZero;
01138     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
01139         aux_xx += coeffs_interior_[jj];
01140     }
01141     hh[ii] = -mtk::kOne*aux_xx;
01142 }
01143
01144 // That is, we construct a system, to solve for the weights.
01145
01146 // Once again we face the challenge of solving with LAPACK. However, for the
01147 // CRSA, this matrix PI is over-determined, since it has more rows than
01148 // unknowns. However, according to the theory, the solution to this system is
01149 // unique. We will use dgels_.
01150
01151 try {
01152     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01153 } catch (std::bad_alloc &memory_allocation_exception) {
01154     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01155         std::endl;
01156     std::cerr << memory_allocation_exception.what() << std::endl;
01157 }

```

```

01161     }
01162     memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01163
01164     int weights_ld{pi.num_cols() + 1};
01165
01166     // Preserve hh.
01167     std::copy(hh, hh + weights_ld, weights_cbs_);
01168
01169     pi.Transpose();
01170
01171     int info{
01172         mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01173             weights_cbs_, weights_ld)
01174     };
01175
01176     #if MTK_DEBUG_LEVEL > 0
01177     if (!info) {
01178         std::cout << "System successfully solved!" << std::endl << std::endl;
01179     } else {
01180         std::cerr << "Error solving system! info = " << info << std::endl;
01181     }
01182     #endif
01183
01184     #if MTK_DEBUG_LEVEL > 0
01185     std::cout << "hh =" << std::endl;
01186     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01187         std::cout << std::setw(11) << hh[ii] << std::endl;
01188     }
01189     std::cout << std::endl;
01190     #endif
01191
01192     // Preserve the original weights for research.
01193
01194     try {
01195         weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01196     } catch (std::bad_alloc &memory_allocation_exception) {
01197         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01198             std::endl;
01199         std::cerr << memory_allocation_exception.what() << std::endl;
01200     }
01201     memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01202
01203     std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01204
01205     #if MTK_DEBUG_LEVEL > 0
01206     std::cout << "weights_CRSA + lambda =" << std::endl;
01207     for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01208         std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01209     }
01210     std::cout << std::endl;
01211     #endif
01212
01213     if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01214
01215         int minrow{std::numeric_limits<int>::infinity()};
01216
01217         mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
01218             order_accuracy_)};
01219         mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01220
01221
01222         mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01223
01224         // 6.1. Insert preliminary approximations to first set of columns.
01225
01226         for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01227             for (auto jj = 0; jj < num_bndy_approx_ + 1; ++jj) {
01228                 phi.data()[ii*(order_accuracy_ + 1) + jj] =
01229                     prem_apps[ii*num_bndy_approx_ + jj];
01230             }
01231         }
01232
01233         // 6.2. Skip a column and negate preliminary approximations.
01234
01235         for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01236             for (auto ii = 1; ii < num_bndy_approx_ + 1; ++ii) {
01237                 auto de = (ii + order_accuracy_ - num_bndy_approx_ + jj*order_accuracy_);
01238                 auto og = (num_bndy_approx_ - ii + (jj)*num_bndy_approx_);
01239                 phi.data()[de] = -pre_apps[og];
01240             }
01241         }
01242     }

```

```

01243     }
01244
01245     // 6.3. Flip negative columns up-down.
01246
01247     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01248         for (auto jj = num_bndy_approx_ + 1; jj < order_accuracy_; jj++) {
01249             auto aux = phi.data()[ii*order_accuracy_ + jj];
01250             phi.data()[ii*order_accuracy_ + jj] =
01251                 phi.data()[ (order_accuracy_ - ii)*order_accuracy_ + jj];
01252             phi.data()[ (order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01253         }
01254     }
01255
01256     // 6.4. Insert stencil.
01257
01258     auto mm = 0;
01259     for (auto jj = num_bndy_approx_ + 1; jj < num_bndy_approx_ + 1; jj++) {
01260         for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01261             if (ii == 0) {
01262                 phi.data()[jj] = 0.0;
01263             } else {
01264                 phi.data()[ (ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01265             }
01266         }
01267         mm++;
01268     }
01269
01270     #if MTK_DEBUG_LEVEL > 0
01271     std::cout << "phi =" << std::endl;
01272     std::cout << phi << std::endl;
01273     #endif
01274
01275     mtk::Real *lamed{}; // Used to build big lambda.
01276
01277     try {
01278         lamed = new mtk::Real[num_bndy_approx_ - 1];
01279     } catch (std::bad_alloc &memory_allocation_exception) {
01280         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01281             std::endl;
01282         std::cerr << memory_allocation_exception.what() << std::endl;
01283     }
01284     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approx_ - 1));
01285
01286     for (auto ii = 0; ii < num_bndy_approx_ - 1; ++ii) {
01287         lamed[ii] = hh[ii + order_accuracy_ + 1];
01288     }
01289
01290     #if MTK_DEBUG_LEVEL > 0
01291     std::cout << "lamed =" << std::endl;
01292     for (auto ii = 0; ii < num_bndy_approx_ - 1; ++ii) {
01293         std::cout << std::setw(12) << lamed[ii] << std::endl;
01294     }
01295     std::cout << std::endl;
01296     #endif
01297
01298     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01299         mtk::Real temp = mtk::kZero;
01300         for (auto jj = 0; jj < num_bndy_approx_ - 1; ++jj) {
01301             temp = temp +
01302                 lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01303         }
01304         hh[ii] = hh[ii] - temp;
01305     }
01306
01307     #if MTK_DEBUG_LEVEL > 0
01308     std::cout << "big_lambda =" << std::endl;
01309     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01310         std::cout << std::setw(12) << hh[ii] << std::endl;
01311     }
01312     std::cout << std::endl;
01313     #endif
01314
01315     int copy_result{}; // Should I replace the solution... not for now.
01316
01317     mtk::Real normerr_; // Norm of the error for the solution on each row.
01318
01319     for (auto row_ = 0; row_ < order_accuracy_ + 1; ++row_) {
01320         normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01321 data(),

```



```

01325                                     order_accuracy_ + 1,
01326                                     order_accuracy_,
01327                                     order_accuracy_,
01328                                     hh,
01329                                     weights_cbs_,
01330                                     row_,
01331                                     mimetic_threshold_,
01332                                     copy_result);
01333     mtk::Real aux{normerr_/norm};
01334
01335     #if MTK_DEBUG_LEVEL>0
01336     std::cout << "Relative norm: " << aux << " " << std::endl;
01337     std::cout << std::endl;
01338     #endif
01339
01340     if (aux < minnorm) {
01341         minnorm = aux;
01342         minrow_ = row_;
01343     }
01344 }
01345
01346 #if MTK_DEBUG_LEVEL > 0
01347 std::cout << "weights_CBSA + lambda (after brute force search):" <<
01348 std::endl;
01349 for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01350     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01351 }
01352 std::cout << std::endl;
01353 #endif
01354
01355 // After we know which row yields the smallest relative norm that row is
01356 // chosen to be the objective function and the result of the optimizer is
01357 // chosen to be the new weights_.
01358
01359 #if MTK_DEBUG_LEVEL > 0
01360 std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01361 minrow_ + 1 << std::endl;
01362 std::cout << std::endl;
01363 #endif
01364 copy_result = 1;
01365 normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
01366 data(),
01367                                     order_accuracy_ + 1,
01368                                     order_accuracy_,
01369                                     order_accuracy_,
01370                                     hh,
01371                                     weights_cbs_,
01372                                     minrow_,
01373                                     mimetic_threshold_,
01374                                     copy_result);
01375
01376 mtk::Real aux_{normerr_/norm};
01377 #if MTK_DEBUG_LEVEL > 0
01378 std::cout << "Relative norm: " << aux_ << std::endl;
01379 std::cout << std::endl;
01380 #endif
01381
01382 delete [] lamed;
01383 lamed = nullptr;
01384 }
01385
01386 delete [] hh;
01387 hh = nullptr;
01388
01389 return true;
01390 }
01391
01392 bool mtk::Grad1D::ComputeStencilBoundaryGrid(void) {
01393 #if MTK_DEBUG_LEVEL > 0
01394 std::cout << "weights_* + lambda =" << std::endl;
01395 for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01396     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01397 }
01398 std::cout << std::endl;
01399 #endif
01400
01401 mtk::Real *lambda{}; // Collection of bottom values from weights_.
01402
01403

```

```

01407     try {
01408         lambda = new mtk::Real[dim_null_];
01409     } catch (std::bad_alloc &memory_allocation_exception) {
01410         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01411             std::endl;
01412         std::cerr << memory_allocation_exception.what() << std::endl;
01413     }
01414     memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01415
01416     for (auto ii = 0; ii < dim_null_; ++ii) {
01417         lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01418     }
01419
01420     #if MTK_DEBUG_LEVEL > 0
01421     std::cout << "lambda =" << std::endl;
01422     for (auto ii = 0; ii < dim_null_; ++ii) {
01423         std::cout << std::setw(12) << lambda[ii] << std::endl;
01424     }
01425     std::cout << std::endl;
01426     #endif
01427
01429     mtk::Real *alpha{}; // Collection of alpha values.
01430
01431
01432     try {
01433         alpha = new mtk::Real[dim_null_];
01434     } catch (std::bad_alloc &memory_allocation_exception) {
01435         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01436             std::endl;
01437         std::cerr << memory_allocation_exception.what() << std::endl;
01438     }
01439     memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01440
01441     for (auto ii = 0; ii < dim_null_; ++ii) {
01442         alpha[ii] = lambda[ii]/weights_cbs_[ii];
01443     }
01444
01445     #if MTK_DEBUG_LEVEL > 0
01446     std::cout << "alpha =" << std::endl;
01447     for (auto ii = 0; ii < dim_null_; ++ii) {
01448         std::cout << std::setw(12) << alpha[ii] << std::endl;
01449     }
01450     std::cout << std::endl;
01451     #endif
01452
01453
01454     try {
01455         mim_bndy_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
01456     } catch (std::bad_alloc &memory_allocation_exception) {
01457         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01458             std::endl;
01459         std::cerr << memory_allocation_exception.what() << std::endl;
01460     }
01461     memset(mim_bndy_,
01462         mtk::kZero,
01463         sizeof(mim_bndy_[0])*num_bndy_coeffs_*num_bndy_approxs_);
01464
01465     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01466         for (auto jj = 0; jj < (num_bndy_approxs_ - 1); ++jj) {
01467             mim_bndy_[ii*num_bndy_approxs_ + jj] =
01468                 prem_apps_[ii*num_bndy_approxs_ + jj] +
01469                 alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01470         }
01471     }
01472
01473     for(auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01474         mim_bndy_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)] =
01475             prem_apps_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)];
01476     }
01477
01478     #if MTK_DEBUG_LEVEL > 0
01479     std::cout << "Collection of mimetic approximations:" << std::endl;
01480     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01481         for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01482             std::cout << std::setw(13) << mim_bndy_[ii*num_bndy_approxs_ + jj];
01483         }
01484         std::cout << std::endl;
01485     }
01486     std::cout << std::endl;
01487     #endif
01488
01489

```

```

01490     delete[] lambda;
01491     lambda = nullptr;
01492
01493     delete[] alpha;
01494     alpha = nullptr;
01495
01496     return true;
01497 }
01498
01499 bool mtk::Grad1D::AssembleOperator(void) {
01500
01501     // The output array will have this form:
01502     // 1. The first entry of the array will contain the used order kk.
01503     // 2. The second entry of the array will contain the collection of
01504     // approximating coefficients for the interior of the grid.
01505     // 3. The third entry will contain a collection of weights.
01506     // 4. The next dim_null - 1 entries will contain the collections of
01507     // approximating coefficients for the west boundary of the grid.
01508
01509     gradient_length_ = 1 + order_accuracy_ + order_accuracy_ +
01510         num_bndy_approxs_*num_bndy_coeffs_;
01511
01512     #if MTK_DEBUG_LEVEL > 0
01513     std::cout << "gradient_length_ = " << gradient_length_ << std::endl;
01514     #endif
01515
01516     try {
01517         gradient_ = new mtk::Real[gradient_length_];
01518     } catch (std::bad_alloc &memory_allocation_exception) {
01519         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01520             std::endl;
01521         std::cerr << memory_allocation_exception.what() << std::endl;
01522     }
01523     memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01524
01525
01526
01527     gradient_[0] = order_accuracy_;
01528
01529
01530
01531     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01532         gradient_[ii + 1] = coeffs_interior_[ii];
01533     }
01534
01535
01536
01537     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01538         gradient_[(order_accuracy_ + 1) + ii] = weights_cbs_[ii];
01539     }
01540
01541
01542
01543     int offset{2*order_accuracy_ + 1};
01544
01545
01546     int aux {}; // Auxiliary variable.
01547
01548     if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01549         for (auto ii = 0; ii < num_bndy_approxs_ ; ii++) {
01550             for (auto jj = 0; jj < num_bndy_coeffs_ ; jj++) {
01551                 gradient_[offset + aux] = mim_bndy_[jj]*num_bndy_approxs_ + ii;
01552                 aux++;
01553             }
01554         }
01555     } else {
01556         gradient_[offset + 0] = prem_apps_[0];
01557         gradient_[offset + 1] = prem_apps_[1];
01558         gradient_[offset + 2] = prem_apps_[2];
01559     }
01560
01561
01562     #if MTK_DEBUG_LEVEL > 0
01563     std::cout << "1d " << order_accuracy_ << "-order grad built!" << std::endl;
01564     std::cout << std::endl;
01565     #endif
01566
01567     return true;
01568 }

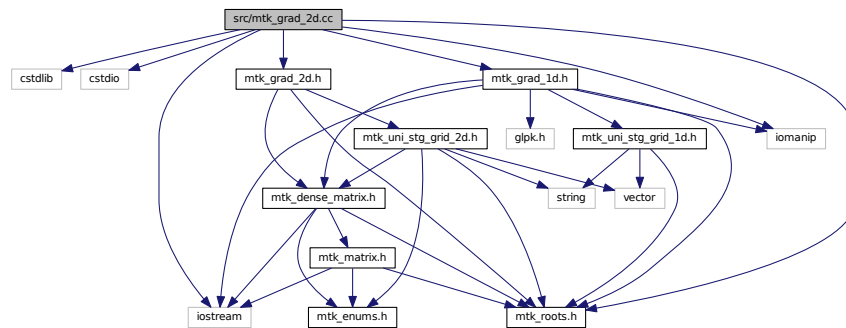
```

17.69 src/mtk_grad_2d.cc File Reference

Implements the class Grad2D.

```
#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_grad_1d.h"
#include "mtk_grad_2d.h"
```

Include dependency graph for mtk_grad_2d.cc:



17.69.1 Detailed Description

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

Author

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

Definition in file [mtk_grad_2d.cc](#).

17.70 mtk_grad_2d.cc

```
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00011 /*
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00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
```

```

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00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_grad_1d.h"
00065 #include "mtk_grad_2d.h"
00066
00067 mtk::Grad2D::Grad2D():
00068     order_accuracy_(),
00069     mimetic_threshold_() {}
00070
00071 mtk::Grad2D::Grad2D(const Grad2D &grad):
00072     order_accuracy_(grad.order_accuracy_),
00073     mimetic_threshold_(grad.mimetic_threshold_) {}
00074
00075 mtk::Grad2D::~~Grad2D() {}
00076
00077 bool mtk::Grad2D::ConstructGrad2D(const
    mtk::UniStgGrid2D &grid,
                                int order_accuracy,
                                mtk::Real mimetic_threshold) {
00078
00079
00080
00081     int num_cells_x = grid.num_cells_x();
00082     int num_cells_y = grid.num_cells_y();
00083
00084     int mx = num_cells_x + 1; // Gx vertical dimension
00085     int nx = num_cells_x + 2; // Gx horizontal dimension
00086     int my = num_cells_y + 1; // Gy vertical dimension
00087     int ny = num_cells_y + 2; // Gy horizontal dimension
00088
00089     mtk::Grad1D grad;
00090
00091     bool info = grad.ConstructGrad1D(order_accuracy, mimetic_threshold);
00092
00093     if (!info) {
00094         std::cerr << "Mimetic grad could not be built." << std::endl;
00095         return info;
00096     }
00097
00098     auto west = grid.west_bndy();
00099     auto east = grid.east_bndy();
00100     auto south = grid.south_bndy();
00101     auto north = grid.east_bndy();
00102
00103     mtk::UniStgGrid1D grid_x(west, east, num_cells_x);
00104     mtk::UniStgGrid1D grid_y(south, north, num_cells_y);
00105
00106     mtk::DenseMatrix Gx(grad.ReturnAsDenseMatrix(grid_x));

```

```

00107 mtk::DenseMatrix Gy(grad.ReturnAsDenseMatrix(grid_y));
00108
00109 bool padded{true};
00110 bool transpose{true};
00111
00112 mtk::DenseMatrix tix(num_cells_x, padded, transpose);
00113 mtk::DenseMatrix tiy(num_cells_y, padded, transpose);
00114
00115 mtk::DenseMatrix gxy(mtk::DenseMatrix::Kron(tiy, Gx));
00116 mtk::DenseMatrix gyx(mtk::DenseMatrix::Kron(Gy, tix));
00117
00118 #if MTK_DEBUG_LEVEL > 0
00119 std::cout << "Gx :" << mx << "by " << nx << std::endl;
00120 std::cout << "Transpose Iy : " << num_cells_y << " by " << ny << std::endl;
00121 std::cout << "Gy :" << my << "by " << ny << std::endl;
00122 std::cout << "Transpose Ix : " << num_cells_x << " by " << nx << std::endl;
00123 std::cout << "Kronecker dimensions Grad 2D" <<
00124     mx*num_cells_y + my*num_cells_x << " by " << nx*ny << std::endl;
00125 #endif
00126
00127 mtk::DenseMatrix g2d(mx*num_cells_y + my*num_cells_x, nx*ny);
00128
00129 for(auto ii = 0; ii < nx*ny; ii++) {
00130     for(auto jj = 0; jj < mx*num_cells_y; jj++) {
00131         g2d.SetValue(jj,ii, gxy.GetValue(jj,ii));
00132     }
00133     for(auto kk = 0; kk < my*num_cells_x; kk++) {
00134         g2d.SetValue(kk + mx*num_cells_y, ii, gyx.GetValue(kk,ii));
00135     }
00136 }
00137
00138 gradient_ = g2d;
00139
00140 return info;
00141 }
00142
00143 mtk::DenseMatrix mtk::Grad2D::ReturnAsDenseMatrix() const {
00144
00145     return gradient_;
00146 }

```

17.71 src/mtk_interp_1d.cc File Reference

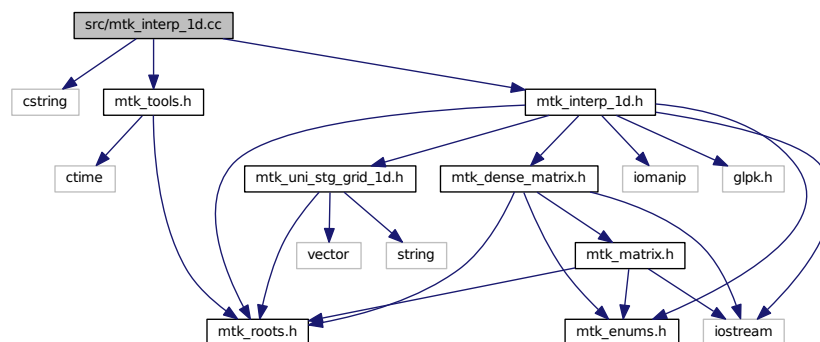
Includes the implementation of the class Interp1D.

```

#include <cstring>
#include "mtk_tools.h"
#include "mtk_interp_1d.h"

```

Include dependency graph for mtk_interp_1d.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

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

17.71.1 Detailed Description

This class implements a 1D interpolation operator.

Author

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

Definition in file [mtk_interp_1d.cc](#).

17.72 mtk_interp_1d.cc

```

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

```

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00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #include <cstring>
00059
00060 #include "mtk_tools.h"
00061
00062 #include "mtk_interp_1d.h"
00063
00064 namespace mtk {
00065
00066 std::ostream& operator <<(std::ostream &stream, mtk::Interp1D &in) {
00067
00068
00069     stream << "coeffs_interior_[1:" << in.order_accuracy_ << "]" = ";
00070     for (auto ii = 0; ii < in.order_accuracy_; ++ii) {
00071         stream << std::setw(9) << in.coeffs_interior_[ii] << " ";
00072     }
00073     stream << std::endl;
00074
00075     return stream;
00076 }
00077
00078 }
00079
00080 mtk::Interp1D::Interp1D():
00081     dir_interp_(mtk::SCALAR_TO_VECTOR),
00082     order_accuracy_(mtk::kDefaultOrderAccuracy),
00083     coeffs_interior_(nullptr) {}
00084
00085 mtk::Interp1D::Interp1D(const Interp1D &interp):
00086     dir_interp_(interp.dir_interp_),
00087     order_accuracy_(interp.order_accuracy_),
00088     coeffs_interior_(interp.coeffs_interior_) {}
00089
00090 mtk::Interp1D::~Interp1D() {
00091
00092     delete[] coeffs_interior_;
00093     coeffs_interior_ = nullptr;
00094 }
00095
00096 bool mtk::Interp1D::ConstructInterp1D(int order_accuracy,
00097     mtk::DirInterp dir) {
00098
00099     #if MTK_DEBUG_LEVEL > 0
00100     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00101     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00102     mtk::Tools::Prevent(dir < mtk::SCALAR_TO_VECTOR &&
00103         dir > mtk::VECTOR_TO_SCALAR,
00104         __FILE__, __LINE__, __func__);
00105
00106     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00107     #endif
00108
00109     order_accuracy_ = order_accuracy;
00110
00111
00112     try {
00113         coeffs_interior_ = new mtk::Real[order_accuracy_];
00114     } catch (std::bad_alloc &memory_allocation_exception) {
00115         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00116             std::endl;
00117         std::cerr << memory_allocation_exception.what() << std::endl;
00118     }
00119     memset(coeffs_interior_,
00120         mtk::kZero,
00121         sizeof(coeffs_interior_[0])*order_accuracy_);
00122
00123     for (int ii = 0; ii < order_accuracy_; ++ii) {
00124         coeffs_interior_[ii] = mtk::kOne;
00125     }
00126
00127     return true;
00128 }
00129
00130 mtk::Real *mtk::Interp1D::coeffs_interior() const {
00131
00132     return coeffs_interior_;
00133 }
00134
00135 mtk::DenseMatrix mtk::Interp1D::ReturnAsDenseMatrix(

```



```

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

```

17.73 src/mtk_lap_1d.cc File Reference

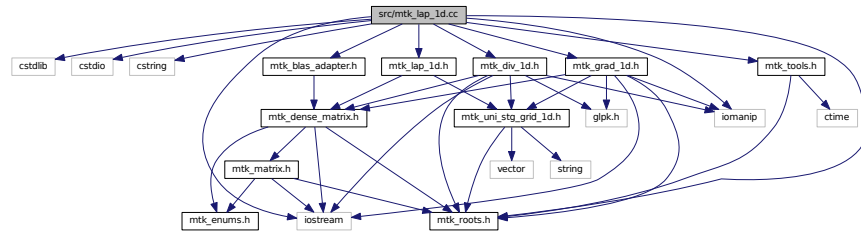
Includes the implementation of the class Lap1D.

```

#include <cstdlib>
#include <stdio>
#include <cstring>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"

```

Include dependency graph for `mtk_lap_1d.cc`:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

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

17.73.1 Detailed Description

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

Author

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

Definition in file [mtk_lap_1d.cc](#).

17.74 mtk_lap_1d.cc

```

00001
00011 /*
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00013 University. All rights reserved.
00014
00015 Redistribution and use in source and binary forms, with or without modification,
00016 are permitted provided that the following conditions are met:
00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00026
00027 3. Redistributions in binary form must reproduce the above copyright notice,
00028 this list of conditions and the following disclaimer in the documentation and/or
00029 other materials provided with the distribution.
00030
00031 4. Usage of the binary form on proprietary applications shall require explicit

```

```

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00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059 #include <cstring>
00060
00061 #include <iostream>
00062 #include <iomanip>
00063
00064 #include "mtk_roots.h"
00065 #include "mtk_tools.h"
00066 #include "mtk_blas_adapter.h"
00067 #include "mtk_grad_1d.h"
00068 #include "mtk_div_1d.h"
00069 #include "mtk_lap_1d.h"
00070
00071 namespace mtk {
00072
00073 std::ostream& operator <<(std::ostream &stream, mtk::Lap1D &in) {
00074
00075     stream << "laplacian_[0] = " << in.laplacian_[0] << std::endl << std::endl;
00076
00077     stream << "laplacian_[1:" << 2*in.order_accuracy_ - 1 << "]" = " <<
00078         std::endl << std::endl;
00079     for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00080         stream << std::setw(13) << in.laplacian_[ii] << " ";
00081     }
00082     stream << std::endl << std::endl;
00083
00084     auto offset = 1 + (2*in.order_accuracy_ - 1);
00085
00086     stream << "laplacian_[ " << offset << ":" << offset +
00087         (in.order_accuracy_ - 1)*(2*in.order_accuracy_ - 1) << "]" = " <<
00088         std::endl << std::endl;
00089     for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00090         for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00091             stream << std::setw(13) <<
00092                 in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00093         }
00094         stream << std::endl;
00095     }
00096     return stream;
00097 }
00098
00099 mtk::Lap1D::Lap1D() :
00100     order_accuracy_(mtk::kDefaultOrderAccuracy),
00101     laplacian_length_(),
00102     mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00103
00104 mtk::Lap1D::~~Lap1D() {
00105     delete [] laplacian_;

```

```

00116     laplacian_ = nullptr;
00117 }
00118
00119 bool mtk::LaplD::ConstructLaplD(int order_accuracy,
00120                                mtk::Real mimetic_threshold) {
00121
00122     #if MTK_DEBUG_LEVEL > 0
00123     mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00124     mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00125     mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00126                         __FILE__, __LINE__, __func__);
00127
00128     if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00129         std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00130     }
00131
00132     std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00133     std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00134     #endif
00135
00136     order_accuracy_ = order_accuracy;
00137     mimetic_threshold_ = mimetic_threshold;
00138
00139
00140
00141     mtk::GradD grad; // Mimetic gradient.
00142
00143     bool info = grad.ConstructGradD(order_accuracy_, mimetic_threshold_);
00144
00145     if (!info) {
00146         std::cerr << "Mimetic grad could not be built." << std::endl;
00147         return false;
00148     }
00149
00150
00151     mtk::DivD div; // Mimetic divergence.
00152
00153     info = div.ConstructDivD(order_accuracy_, mimetic_threshold_);
00154
00155     if (!info) {
00156         std::cerr << "Mimetic div could not be built." << std::endl;
00157         return false;
00158     }
00159
00160
00161
00162
00163     // Since these are mimetic operator, we must multiply the matrices arising
00164     // from both the divergence and the Laplacian, in order to get the
00165     // approximating coefficients for the Laplacian operator.
00166
00167     // However, we must choose a grid that implied a step size of 1, so to get
00168     // the approximating coefficients, without being affected from the
00169     // normalization with respect to the grid.
00170
00171     // Also, the grid must be of the minimum size to support the requested order
00172     // of accuracy. We must please the divergence.
00173
00174     mtk::UniStgGridD aux(mtk::kZero,
00175                         (mtk::Real) 3*order_accuracy_ - 1,
00176                         3*order_accuracy_ - 1);
00177
00178     #if MTK_DEBUG_LEVEL > 0
00179     std::cout << "aux =" << std::endl;
00180     std::cout << aux << std::endl;
00181     std::cout << "aux.delta_x() = " << aux.delta_x() << std::endl;
00182     std::cout << std::endl;
00183     #endif
00184
00185     mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00186
00187     #if MTK_DEBUG_LEVEL > 0
00188     std::cout << "grad_m =" << std::endl;
00189     std::cout << grad_m << std::endl;
00190     #endif
00191
00192     mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00193
00194     #if MTK_DEBUG_LEVEL > 0
00195     std::cout << "div_m =" << std::endl;
00196     std::cout << div_m << std::endl;
00197     #endif
00198
00199
00200

```

```

00203     mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00204
00205     lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00206
00207     #if MTK_DEBUG_LEVEL > 0
00208         std::cout << "lap =" << std::endl;
00209         std::cout << lap << std::endl;
00210     #endif
00211
00212
00213
00214
00215
00216     // The output array will have this form:
00217     // 1. The first entry of the array will contain the used order kk.
00218     // 2. The second entry of the array will contain the collection of
00219     // approximating coefficients for the interior of the grid.
00220     // 3. The next entries will contain the collections of approximating
00221     // coefficients for the west boundary of the grid.
00222
00223     laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00224         (order_accuracy_ - 1)*(2*order_accuracy_);
00225
00226     #if MTK_DEBUG_LEVEL > 0
00227         std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00228         std::cout << std::endl;
00229     #endif
00230
00231     try {
00232         laplacian_ = new mtk::Real[laplacian_length_];
00233     } catch (std::bad_alloc &memory_allocation_exception) {
00234         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00235             std::endl;
00236         std::cerr << memory_allocation_exception.what() << std::endl;
00237     }
00238     memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00239
00240
00241
00242     laplacian_[0] = order_accuracy_;
00243
00244
00245
00246     for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00247         laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00248     }
00249
00250
00251
00252
00253     auto offset = 1 + (2*order_accuracy_ - 1);
00254
00255     for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00256         for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00257             laplacian_[offset + ii*(2*order_accuracy_) + jj] =
00258                 lap.GetValue(1 + ii, jj);
00259         }
00260     }
00261
00262     return true;
00263 }
00264
00265 mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix(
00266     const UniStgGrid1D &grid) const {
00267
00268     int nn{grid.num_cells_x()}; // Number of cells on the grid.
00269
00270     #if MTK_DEBUG_LEVEL > 0
00271         mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00272         mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00273     #endif
00274
00275     mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00276
00277     mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
00278     dx^2.
00279
00280
00281     auto offset = (1 + 2*order_accuracy_ - 1);
00282
00283     for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00284         for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00285             lap.SetValue(1 + ii,
00286                 jj,
00287                 idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00288         }
00289     }

```

```

00290
00292
00293     offset = 1 + (order_accuracy_ - 1);
00294
00295     int kk{1};
00296     for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00297         int mm{1};
00298         for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00299             lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00300             mm = mm + 1;
00301         }
00302         kk = kk + 1;
00303     }
00304
00306
00307     offset = (1 + 2*order_accuracy_ - 1);
00308
00309     auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00310
00311     auto ll = 1;
00312     auto rr = 1;
00313     for (auto ii = nn; ii > aux - 1; --ii) {
00314         auto cc = 0;
00315         for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00316             lap.SetValue(ii, jj, lap.GetValue(rr, cc));
00317             ++ll;
00318             ++cc;
00319         }
00320         rr++;
00321     }
00322
00329
00330     return lap;
00331 }
00332
00333 const mtk::Real* mtk::Lap1D::data(const UniStgGrid1D &grid) const {
00334
00335     mtk::DenseMatrix tmp;
00336
00337     tmp = ReturnAsDenseMatrix(grid);
00338
00339     return tmp.data();
00340 }

```

17.75 src/mtk_lap_2d.cc File Reference

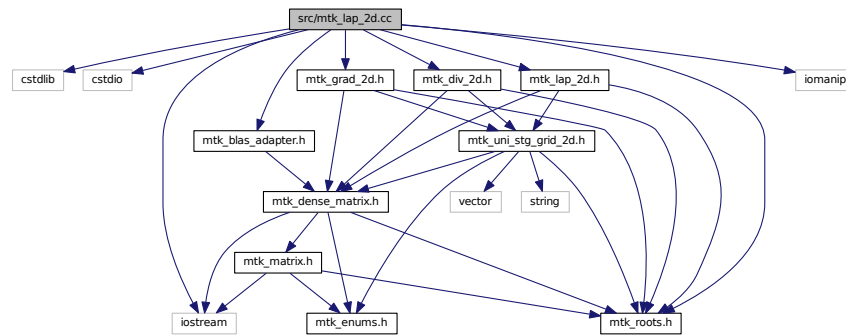
Includes the implementation of the class Lap2D.

```

#include <cstdlib>
#include <cstdio>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_2d.h"
#include "mtk_div_2d.h"
#include "mtk_lap_2d.h"

```

Include dependency graph for mtk_lap_2d.cc:



17.75.1 Detailed Description

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

Author

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

Definition in file [mtk_lap_2d.cc](#).

17.76 mtk_lap_2d.cc

```

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00017
00018 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00019 and a copy of the modified files should be reported once modifications are
00020 completed, unless these modifications are made through the project's GitHub
00021 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00022 should be developed and included in any deliverable.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

```

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00051 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #include <cstdlib>
00058 #include <cstdio>
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "mtk_roots.h"
00064 #include "mtk_blas_adapter.h"
00065 #include "mtk_grad_2d.h"
00066 #include "mtk_div_2d.h"
00067 #include "mtk_lap_2d.h"
00068
00069 mtk::Lap2D::Lap2D(): order_accuracy_(), mimetic_threshold_() {}
00070
00071 mtk::Lap2D::Lap2D(const Lap2D &lap):
00072     order_accuracy_(lap.order_accuracy_),
00073     mimetic_threshold_(lap.mimetic_threshold_) {}
00074
00075 mtk::Lap2D::~~Lap2D() {}
00076
00077 bool mtk::Lap2D::ConstructLap2D(const
    mtk::UniStgGrid2D &grid,
                                int order_accuracy,
                                mtk::Real mimetic_threshold) {
00078
00079
00080
00081     int num_cells_x{grid.num_cells_x()};
00082     int num_cells_y{grid.num_cells_y()};
00083     int aux{(num_cells_x + 2)*(num_cells_y + 2)};
00084
00085     mtk::Grad2D gg;
00086     mtk::Div2D dd;
00087
00088     bool info{gg.ConstructGrad2D(grid, order_accuracy, mimetic_threshold)};
00089
00090     if (!info) {
00091         std::cerr << "Mimetic lap could not be built." << std::endl;
00092         return info;
00093     }
00094
00095     info = dd.ConstructDiv2D(grid, order_accuracy, mimetic_threshold);
00096
00097     if (!info) {
00098         std::cerr << "Mimetic div could not be built." << std::endl;
00099         return info;
00100     }
00101
00102     mtk::DenseMatrix ggm{gg.ReturnAsDenseMatrix()};
00103     mtk::DenseMatrix ddm{dd.ReturnAsDenseMatrix()};
00104
00105     laplacian_ = mtk::BLASAdapter::RealDenseMM(ddm, ggm);
00106
00107     return info;
00108 }
00109
00110 mtk::DenseMatrix mtk::Lap2D::ReturnAsDenseMatrix() const {
00111
00112     return laplacian_;
00113 }
00114
00115 mtk::Real *mtk::Lap2D::data() const {
00116
00117     return laplacian_.data();
00118 }

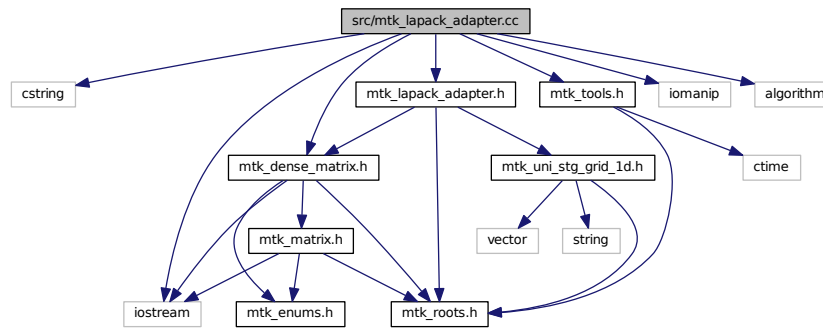
```


17.77 src/mtk_lapack_adapter.cc File Reference

Adapter class for the LAPACK API.

```
#include <cstring>
#include <iostream>
#include <iomanip>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_dense_matrix.h"
#include "mtk_lapack_adapter.h"
```

Include dependency graph for mtk_lapack_adapter.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

- void [mtk::sgesv_](#) (int *n, int *nrhs, Real *a, int *lda, int *ipiv, Real *b, int *ldb, int *info)
- void [mtk::sgels_](#) (char *trans, int *m, int *n, int *nrhs, Real *a, int *lda, Real *b, int *ldb, Real *work, int *lwork, int *info)

Single-precision GEneral matrix Least Squares solver.

- void [mtk::sgeqrf_](#) (int *m, int *n, Real *a, int *lda, Real *tau, Real *work, int *lwork, int *info)

Single-precision GEneral matrix QR Factorization.

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

Single-precision Orthogonal [Matrix](#) from QR factorization.

17.77.1 Detailed Description

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

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

See also

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

Todo Write documentation using LaTeX.

Author

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

Definition in file [mtk_lapack_adapter.cc](#).

17.78 mtk_lapack_adapter.cc

```

00001
00021 /*
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00023 University. All rights reserved.
00024
00025 Redistribution and use in source and binary forms, with or without modification,
00026 are permitted provided that the following conditions are met:
00027
00028 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00029 and a copy of the modified files should be reported once modifications are
00030 completed, unless these modifications are made through the project's GitHub
00031 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00032 should be developed and included in any deliverable.
00033
00034 2. Redistributions of source code must be done through direct
00035 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00036
00037 3. Redistributions in binary form must reproduce the above copyright notice,
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00062 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00063 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00064 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00065 */
00066
00067 #include <cstring>
00068
00069 #include <iostream>
00070 #include <iomanip>

```

```
00071
00072 #include <algorithm>
00073
00074 #include "mtk_tools.h"
00075 #include "mtk_dense_matrix.h"
00076 #include "mtk_lapack_adapter.h"
00077
00078 namespace mtk {
00079
00080 extern "C" {
00081
00082 #ifdef MTK_PRECISION_DOUBLE
00083
00102 void dgesv_(int* n,
00103             int* nrhs,
00104             Real* a,
00105             int* lda,
00106             int* ipiv,
00107             Real* b,
00108             int* ldb,
00109             int* info);
00110 #else
00111
00130 void sgesv_(int* n,
00131             int* nrhs,
00132             Real* a,
00133             int* lda,
00134             int* ipiv,
00135             Real* b,
00136             int* ldb,
00137             int* info);
00138 #endif
00139
00140 #ifdef MTK_PRECISION_DOUBLE
00141
00184 void dgels_(char* trans,
00185             int* m,
00186             int* n,
00187             int* nrhs,
00188             Real* a,
00189             int* lda,
00190             Real* b,
00191             int* ldb,
00192             Real* work,
00193             int* lwork,
00194             int* info);
00195 #else
00196
00239 void sgels_(char* trans,
00240             int* m,
00241             int* n,
00242             int* nrhs,
00243             Real* a,
00244             int* lda,
00245             Real* b,
00246             int* ldb,
00247             Real* work,
00248             int* lwork,
00249             int* info);
00250 #endif
00251
00252 #ifdef MTK_PRECISION_DOUBLE
00253
00282 void dgeqrf_(int *m,
00283              int *n,
00284              Real *a,
00285              int *lda,
00286              Real *tau,
00287              Real *work,
00288              int *lwork,
00289              int *info);
00290 #else
00291
00320 void sgeqrf_(int *m,
00321              int *n,
00322              Real *a,
00323              int *lda,
00324              Real *tau,
00325              Real *work,
00326              int *lwork,
00327              int *info);
```

```

00328 #endif
00329
00330 #ifdef MTK_PRECISION_DOUBLE
00331
00365 void dormqr_(char *side,
00366              char *trans,
00367              int *m,
00368              int *n,
00369              int *k,
00370              Real *a,
00371              int *lda,
00372              Real *tau,
00373              Real *c,
00374              int *ldc,
00375              Real *work,
00376              int *lwork,
00377              int *info);
00378 #else
00379
00413 void sormqr_(char *side,
00414              char *trans,
00415              int *m,
00416              int *n,
00417              int *k,
00418              Real *a,
00419              int *lda,
00420              Real *tau,
00421              Real *c,
00422              int *ldc,
00423              Real *work,
00424              int *lwork,
00425              int *info);
00426 #endif
00427 }
00428 }
00429
00430 int mtk::LAPACKAdapter::SolveDenseSystem(
    mtk::DenseMatrix &mm,
    mtk::Real *rhs) {
00431
00432
00433     #if MTK_DEBUG_LEVEL > 0
00434     mtk::Tools::Prevent(rhs == nullptr, __FILE__, __LINE__, __func__);
00435     #endif
00436
00437     int *ipiv{};           // Array for pivoting information.
00438     int nrhs{1};          // Number of right-hand sides.
00439     int info{};            // Status of the solution.
00440     int mm_rank{mm.num_rows()}; // Rank of the matrix.
00441
00442     try {
00443         ipiv = new int[mm_rank];
00444     } catch (std::bad_alloc &memory_allocation_exception) {
00445         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00446         std::endl;
00447         std::cerr << memory_allocation_exception.what() << std::endl;
00448     }
00449     memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00450
00451     int ldbb = mm_rank;
00452     int mm_ld = mm_rank;
00453
00454     #ifdef MTK_PRECISION_DOUBLE
00455     dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00456     #else
00457     fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00458     #endif
00459
00460     delete [] ipiv;
00461
00462     return info;
00463 }
00464
00465 int mtk::LAPACKAdapter::SolveDenseSystem(
    mtk::DenseMatrix &mm,
    mtk::DenseMatrix &bb) {
00466
00467     int nrhs{bb.num_rows()}; // Number of right-hand sides.
00468
00469     #if MTK_DEBUG_LEVEL > 0
00470     mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00471     #endif

```

```

00473
00474     int *ipiv{};                // Array for pivoting information.
00475     int info{};                // Status of the solution.
00476     int mm_rank{mm.num_rows()}; // Rank of the matrix.
00477
00478     try {
00479         ipiv = new int[mm_rank];
00480     } catch (std::bad_alloc &memory_allocation_exception) {
00481         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00482             std::endl;
00483         std::cerr << memory_allocation_exception.what() << std::endl;
00484     }
00485     memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00486
00487     int ldbb = mm_rank;
00488     int mm_ld = mm_rank;
00489
00490     #ifdef MTK_PRECISION_DOUBLE
00491     dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00492     #else
00493     fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00494     #endif
00495
00496     delete [] ipiv;
00497
00498     // After output, the data in the matrix will be column-major ordered.
00499
00500     bb.SetOrdering(mtk::COL_MAJOR);
00501
00502     #if MTK_DEBUG_LEVEL > 0
00503     std::cout << "bb_col_maj_ord =" << std::endl;
00504     std::cout << bb << std::endl;
00505     #endif
00506
00507     bb.OrderRowMajor();
00508
00509     #if MTK_DEBUG_LEVEL > 0
00510     std::cout << "bb_row_maj_ord =" << std::endl;
00511     std::cout << bb << std::endl;
00512     #endif
00513
00514     return info;
00515 }
00516
00517 int mtk::LAPACKAdapter::SolveDenseSystem(
00518     mtk::DenseMatrix &mm,
00519                                     mtk::UniStgGrid1D &rhs) {
00520
00521     int nrhs{1}; // Number of right-hand sides.
00522
00523     int *ipiv{};                // Array for pivoting information.
00524     int info{};                // Status of the solution.
00525     int mm_rank{mm.num_rows()}; // Rank of the matrix.
00526
00527     try {
00528         ipiv = new int[mm_rank];
00529     } catch (std::bad_alloc &memory_allocation_exception) {
00530         std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00531             std::endl;
00532         std::cerr << memory_allocation_exception.what() << std::endl;
00533     }
00534     memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00535
00536     int ldbb = mm_rank;
00537     int mm_ld = mm_rank;
00538
00539     mm.OrderColMajor();
00540
00541     #ifdef MTK_PRECISION_DOUBLE
00542     dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00543         rhs.discrete_field_u(), &ldbb, &info);
00544     #else
00545     fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv,
00546         rhs.discrete_field_u(), &ldbb, &info);
00547     #endif
00548
00549     mm.OrderRowMajor();
00550
00551     delete [] ipiv;
00552
00553     return info;

```

```

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

```

```

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

```

```

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

```



```

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

```

17.79 src/mtk_matrix.cc File Reference

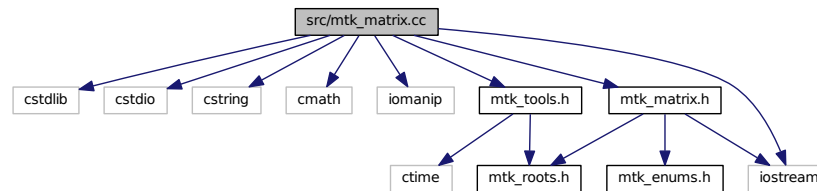
Implementing the representation of a matrix in the MTK.

```

#include <cstdlib>
#include <cstdio>
#include <cstring>
#include <cmath>
#include <iomanip>
#include <iostream>
#include "mtk_tools.h"
#include "mtk_matrix.h"

```

Include dependency graph for `mtk_matrix.cc`:



17.79.1 Detailed Description

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

Author

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

Definition in file [mtk_matrix.cc](#).

17.80 mtk_matrix.cc

```

00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00025
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```

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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <cstdlib>
00057 #include <cstdio>
00058 #include <cstring>
00059 #include <cmath>
00060
00061 #include <iomanip>
00062 #include <iostream>
00063
00064 #include "mtk_tools.h"
00065 #include "mtk_matrix.h"
00066
00067 mtk::Matrix::Matrix():
00068     storage_(mtk::DENSE),
00069     ordering_(mtk::ROW_MAJOR),
00070     num_rows_(),
00071     num_cols_(),
00072     num_values_(),
00073     ld_(),
00074     num_zero_(),
00075     num_non_zero_(),
00076     num_null_(),
00077     num_non_null_(),
00078     kl_(),
00079     ku_(),
00080     bandwidth_(),
00081     abs_density_(),
00082     rel_density_(),
00083     abs_sparsity_(),
00084     rel_sparsity_() {}
00085
00086 mtk::Matrix::Matrix(const Matrix &in):
00087     storage_(in.storage_),
00088     ordering_(in.ordering_),
00089     num_rows_(in.num_rows_),
00090     num_cols_(in.num_cols_),
00091     num_values_(in.num_values_),
00092     ld_(in.ld_),
00093     num_zero_(in.num_zero_),
00094     num_non_zero_(in.num_non_zero_),
00095     num_null_(in.num_null_),
00096     num_non_null_(in.num_non_null_),
00097     kl_(in.kl_),
00098     ku_(in.ku_),
00099     bandwidth_(in.bandwidth_),
00100     abs_density_(in.abs_density_),
00101     rel_density_(in.rel_density_),
00102     abs_sparsity_(in.abs_sparsity_),
00103     rel_sparsity_(in.rel_sparsity_) {}
00104
00105 mtk::Matrix::~Matrix() {}
00106
00107 mtk::MatrixStorage mtk::Matrix::storage() const {
00108
00109     return storage_;
00110 }
00111
00112 mtk::MatrixOrdering mtk::Matrix::ordering() const {
00113
00114     return ordering_;
00115 }
00116
00117 int mtk::Matrix::num_rows() const {
00118
00119     return num_rows_;
00120 }
00121
00122 int mtk::Matrix::num_cols() const {
00123
00124     return num_cols_;
00125 }
00126
00127 int mtk::Matrix::num_values() const {
00128
00129     return num_values_;

```

```

00130 }
00131
00132 int mtk::Matrix::ld() const {
00133     return ld_;
00134 }
00135
00136 int mtk::Matrix::num_zero() const {
00137     return num_zero_;
00138 }
00139
00140 int mtk::Matrix::num_non_zero() const {
00141     return num_non_zero_;
00142 }
00143
00144 int mtk::Matrix::num_null() const {
00145     return num_null_;
00146 }
00147
00148 int mtk::Matrix::num_non_null() const {
00149     return num_non_null_;
00150 }
00151
00152 int mtk::Matrix::kl() const {
00153     return kl_;
00154 }
00155
00156 int mtk::Matrix::ku() const {
00157     return ku_;
00158 }
00159
00160 int mtk::Matrix::bandwidth() const {
00161     return bandwidth_;
00162 }
00163
00164 mtk::Real mtk::Matrix::rel_density() const {
00165     return rel_density_;
00166 }
00167
00168 mtk::Real mtk::Matrix::abs_sparsity() const {
00169     return abs_sparsity_;
00170 }
00171
00172 mtk::Real mtk::Matrix::rel_sparsity() const {
00173     return rel_sparsity_;
00174 }
00175
00176 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss) {
00177     #if MTK_DEBUG_LEVEL > 0
00178     mtk::Tools::Prevent(!(ss == mtk::DENSE ||
00179                          ss == mtk::Banded ||
00180                          ss == mtk::CRS),
00181                        __FILE__, __LINE__, __func__);
00182     #endif
00183     storage_ = ss;
00184 }
00185
00186 void mtk::Matrix::set_ordering(const
00187 mtk::MatrixOrdering &oo) {
00188     #if MTK_DEBUG_LEVEL > 0
00189     mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
00190                          mtk::COL_MAJOR),
00191                        __FILE__, __LINE__, __func__);
00192     #endif
00193     ordering_ = oo;
00194     ld_ = (ordering_ == mtk::ROW_MAJOR)?

```

```

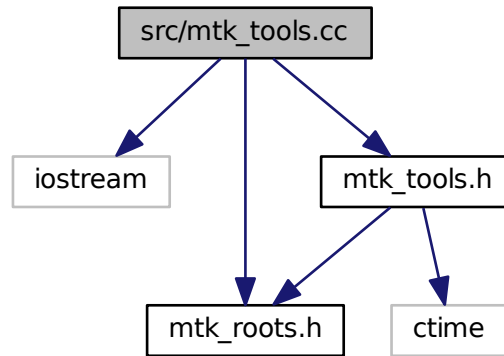
00209     std::max(1,num_cols_): std::max(1,num_rows_);
00210 }
00211
00212 void mtk::Matrix::set_num_rows(int in) {
00213
00214     #if MTK_DEBUG_LEVEL > 0
00215     mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00216     #endif
00217
00218     num_rows_ = in;
00219     num_values_ = num_rows_*num_cols_;
00220     ld_ = (ordering_ == mtk::ROW_MAJOR)?
00221         std::max(1,num_cols_): std::max(1,num_rows_);
00222 }
00223
00224 void mtk::Matrix::set_num_cols(int in) {
00225
00226     #if MTK_DEBUG_LEVEL > 0
00227     mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00228     #endif
00229
00230     num_cols_ = in;
00231     num_values_ = num_rows_*num_cols_;
00232     ld_ = (ordering_ == mtk::ROW_MAJOR)?
00233         std::max(1,num_cols_): std::max(1,num_rows_);
00234 }
00235
00236 void mtk::Matrix::set_num_zero(int in) {
00237
00238     #if MTK_DEBUG_LEVEL > 0
00239     mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00240     #endif
00241
00242     num_zero_ = in;
00243     num_non_zero_ = num_values_ - num_zero_;
00244
00245     rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00246     rel_sparsity_ = 1.0 - rel_density_;
00247 }
00248
00249
00250 void mtk::Matrix::set_num_null(int in) {
00251
00252     #if MTK_DEBUG_LEVEL > 0
00253     mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00254     #endif
00255
00256     num_null_ = in;
00257     num_non_null_ = num_values_ - num_null_;
00258
00259     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00260     abs_sparsity_ = 1.0 - abs_density_;
00261 }
00262
00263
00264 void mtk::Matrix::IncreaseNumZero() {
00265
00266     num_zero_++;
00267     num_non_zero_ = num_values_ - num_zero_;
00268     rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00269     rel_sparsity_ = 1.0 - rel_density_;
00270 }
00271
00272
00273 void mtk::Matrix::IncreaseNumNull() {
00274
00275     num_null_++;
00276     num_non_null_ = num_values_ - num_null_;
00277     abs_density_ = (mtk::Real) num_non_null_/num_values_;
00278     abs_sparsity_ = 1.0 - abs_density_;
00279 }
00280
00281
00282 }

```

17.81 src/mtk_tools.cc File Reference

Implements a execution tool manager class.

```
#include <iostream>
#include "mtk_roots.h"
#include "mtk_tools.h"
Include dependency graph for mtk_tools.cc:
```



17.81.1 Detailed Description

Basic tools to ensure execution correctness.

Author

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

Definition in file [mtk_tools.cc](#).

17.82 mtk_tools.cc

```
00001
00010 /*
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00012 University. All rights reserved.
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00015 are permitted provided that the following conditions are met:
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00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed, unless these modifications are made through the project's GitHub
00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
00022
00023 2. Redistributions of source code must be done through direct
00024 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

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00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057
00058 #include "mtk_roots.h"
00059 #include "mtk_tools.h"
00060
00061 void mtk::Tools::Prevent(const bool condition,
00062                          const char *fname,
00063                          int lineno,
00064                          const char *fxname) {
00065
00066     #if MTK_DEBUG_LEVEL > 0
00067     if (lineno < 1) {
00070         std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00071         __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00072         exit(EXIT_FAILURE);
00073     }
00074     #endif
00075
00076     if (condition) {
00077         std::cerr << fname << ": " << "Incorrect parameter at line " <<
00078         lineno << " (" << fxname << ")" << std::endl;
00079         exit(EXIT_FAILURE);
00080     }
00081 }
00082
00083
00084
00085 int mtk::Tools::test_number_; // Used to control the correctness of the test.
00086
00087 mtk::Real mtk::Tools::duration_; // Duration of the current test.
00088
00089 clock_t mtk::Tools::begin_time_; // Used to time tests.
00090
00091 void mtk::Tools::BeginUnitTestNo(const int &nn) {
00092
00093     #if MTK_DEBUG_LEVEL > 0
00094     mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00095     #endif
00096
00097     test_number_ = nn;
00098
00099     #if MTK_DEBUG_LEVEL > 0
00100     std::cout << "Beginning test " << nn << "." << std::endl;
00101     #endif
00102     begin_time_ = clock();
00103 }
00104
00105 void mtk::Tools::EndUnitTestNo(const int &nn) {
00106
00107     #if MTK_DEBUG_LEVEL > 0
00108     mtk::Tools::Prevent(test_number_ != nn, __FILE__, __LINE__, __func__);
00109     #endif
00110
00111     duration_ = mtk::Real(clock() - begin_time_)/CLOCKS_PER_SEC;
00112 }
00113
00114 void mtk::Tools::Assert(const bool condition) {

```

```

00115
00116     if (condition) {
00117         std::cout << "Test " << test_number_ << ": PASSED in " << duration_ <<
00118             " s." << std::endl;
00119     } else {
00120         std::cout << "Test " << test_number_ << ": FAILED in " << duration_ <<
00121             " s." << std::endl;
00122     }
00123 }

```

17.83 src/mtk_uni_stg_grid_1d.cc File Reference

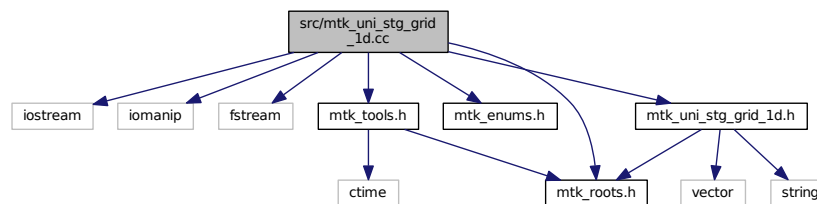
Implementation of an 1D uniform staggered grid.

```

#include <iostream>
#include <iomanip>
#include <fstream>
#include "mtk_roots.h"
#include "mtk_enums.h"
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_1d.h"

```

Include dependency graph for mtk_uni_stg_grid_1d.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

- `std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid1D &in)`

17.83.1 Detailed Description

Implementation of an 1D uniform staggered grid.

Author

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

Definition in file [mtk_uni_stg_grid_1d.cc](#).

17.84 mtk_uni_stg_grid_1d.cc

```

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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 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_enums.h"
00062 #include "mtk_tools.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00068 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid1D &in) {
00069
00070     stream << '[' << in.west_bndy_x << ':' << in.num_cells_x << ':' <<
00071     in.east_bndy_x << "]" = " << std::endl << std::endl;
00072
00073
00074
00075     stream << "x:";
00076     for (unsigned int ii = 0; ii < in.discrete_domain_x.size(); ++ii) {
00077         stream << std::setw(10) << in.discrete_domain_x[ii];
00078     }
00079     stream << std::endl;
00080
00081
00082
00083     if (in.nature_ == mtk::SCALAR) {
00084         stream << "u:";
00085     }
00086     else {
00087         stream << "v:";
00088     }

```

```

00089     for (unsigned int ii = 0; ii < in.discrete_field_u_.size(); ++ii) {
00090         stream << std::setw(10) << in.discrete_field_u_[ii];
00091     }
00092
00093     stream << std::endl;
00094
00095     return stream;
00096 }
00097 }
00098
00099 mtk::UniStgGrid1D::UniStgGrid1D() :
00100     nature_(),
00101     discrete_domain_x_(),
00102     discrete_field_u_(),
00103     west_bndy_x_(),
00104     east_bndy_x_(),
00105     num_cells_x_(),
00106     delta_x_() {}
00107
00108 mtk::UniStgGrid1D::UniStgGrid1D(const
00109     UniStgGrid1D &grid):
00110     nature_(grid.nature_),
00111     west_bndy_x_(grid.west_bndy_x_),
00112     east_bndy_x_(grid.east_bndy_x_),
00113     num_cells_x_(grid.num_cells_x_),
00114     delta_x_(grid.delta_x_) {
00115
00116     std::copy(grid.discrete_domain_x_.begin(),
00117         grid.discrete_domain_x_.begin() + grid.
00118         discrete_domain_x_.size(),
00119         discrete_domain_x_.begin());
00120
00121     std::copy(grid.discrete_field_u_.begin(),
00122         grid.discrete_field_u_.begin() + grid.
00123         discrete_field_u_.size(),
00124         discrete_field_u_.begin());
00125 }
00126
00127 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00128     const Real &east_bndy_x,
00129     const int &num_cells_x,
00130     const mtk::FieldNature &nature) {
00131
00132     #if MTK_DEBUG_LEVEL > 0
00133     mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00134     mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00135     mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00136     mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00137     #endif
00138
00139     nature_ = nature;
00140     west_bndy_x_ = west_bndy_x;
00141     east_bndy_x_ = east_bndy_x;
00142     num_cells_x_ = num_cells_x;
00143
00144     delta_x_ = (east_bndy_x - west_bndy_x) / ((mtk::Real) num_cells_x);
00145 }
00146
00147 mtk::UniStgGrid1D::~~UniStgGrid1D() {}
00148
00149 mtk::Real mtk::UniStgGrid1D::west_bndy_x() const {
00150
00151     return west_bndy_x_;
00152 }
00153
00154 mtk::Real mtk::UniStgGrid1D::east_bndy_x() const {
00155
00156     return east_bndy_x_;
00157 }
00158
00159 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00160
00161     return delta_x_;
00162 }
00163
00164 const mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() const
00165 {
00166
00167     return discrete_domain_x_.data();
00168 }

```

```

00166 mtk::Real *mtk::UniStgGrid1D::discrete_field_u() {
00167
00168     return discrete_field_u_.data();
00169 }
00170
00171 int mtk::UniStgGrid1D::num_cells_x() const {
00172
00173     return num_cells_x_;
00174 }
00175
00176 void mtk::UniStgGrid1D::BindScalarField(
00177     mtk::Real (*ScalarField)(mtk::Real xx)) {
00178
00179     #if MTK_DEBUG_LEVEL > 0
00180     mtk::Tools::Prevent(nature_ == mtk::VECTOR, __FILE__, __LINE__, __func__);
00181     #endif
00182
00183
00184     discrete_domain_x_.reserve(num_cells_x_ + 2);
00185
00186     discrete_domain_x_.push_back(west_bndy_x_);
00187     #ifdef MTK_PRECISION_DOUBLE
00188     auto first_center = west_bndy_x_ + delta_x_/2.0;
00189     #else
00190     auto first_center = west_bndy_x_ + delta_x_/2.0f;
00191     #endif
00192     discrete_domain_x_.push_back(first_center);
00193     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00194         discrete_domain_x_.push_back(first_center + ii*delta_x_);
00195     }
00196     discrete_domain_x_.push_back(east_bndy_x_);
00197
00198
00199     discrete_field_u_.reserve(num_cells_x_ + 2);
00200
00201     discrete_field_u_.push_back(ScalarField(west_bndy_x_));
00202
00203     discrete_field_u_.push_back(ScalarField(first_center));
00204     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00205         discrete_field_u_.push_back(ScalarField(first_center + ii*delta_x_));
00206     }
00207     discrete_field_u_.push_back(ScalarField(east_bndy_x_));
00208 }
00209
00210 void mtk::UniStgGrid1D::BindVectorField(
00211     mtk::Real (*VectorField)(mtk::Real xx)) {
00212
00213     #if MTK_DEBUG_LEVEL > 0
00214     mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00215     #endif
00216
00217
00218     discrete_domain_x_.reserve(num_cells_x_ + 1);
00219
00220     discrete_domain_x_.push_back(west_bndy_x_);
00221     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00222         discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00223     }
00224     discrete_domain_x_.push_back(east_bndy_x_);
00225
00226
00227     discrete_field_u_.reserve(num_cells_x_ + 1);
00228
00229     discrete_field_u_.push_back(VectorField(west_bndy_x_));
00230     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00231         discrete_field_u_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00232     }
00233     discrete_field_u_.push_back(VectorField(east_bndy_x_));
00234 }
00235
00236 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00237     std::string space_name,
00238     std::string field_name) const {
00239
00240     std::ofstream output_dat_file; // Output file.
00241
00242     output_dat_file.open(filename);
00243
00244     if (!output_dat_file.is_open()) {
00245         return false;
00246     }
00247 }

```

```

00251
00252 output_dat_file << "# " << space_name << ' ' << field_name << std::endl;
00253 for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00254     output_dat_file << discrete_domain_x_[ii] << ' ' << discrete_field_u_[ii] <<
00255         std::endl;
00256 }
00257
00258 output_dat_file.close();
00259
00260 return true;
00261 }

```

17.85 src/mtk_uni_stg_grid_2d.cc File Reference

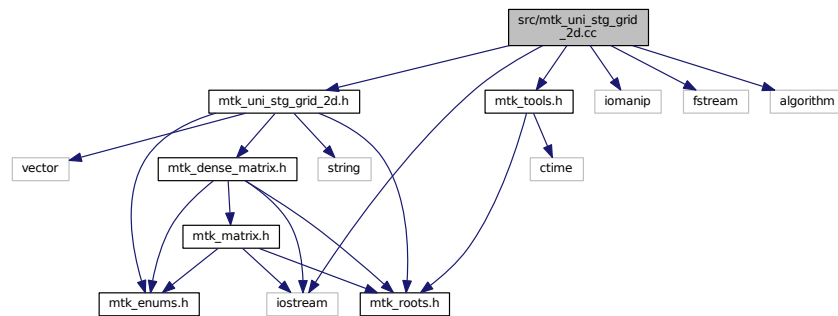
Implementation of a 2D uniform staggered grid.

```

#include <iostream>
#include <iomanip>
#include <fstream>
#include <algorithm>
#include "mtk_tools.h"
#include "mtk_uni_stg_grid_2d.h"

```

Include dependency graph for mtk_uni_stg_grid_2d.cc:



Namespaces

- [mtk](#)

Mimetic Methods Toolkit namespace.

Functions

- `std::ostream & mtk::operator<< (std::ostream &stream, mtk::UniStgGrid2D &in)`

17.85.1 Detailed Description

Implementation of a 2D uniform staggered grid.

Author

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

Definition in file [mtk_uni_stg_grid_2d.cc](#).

17.86 mtk_uni_stg_grid_2d.cc

```

00001
00010 /*
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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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00043
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00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include <algorithm>
00061
00062 #include "mtk_tools.h"
00063 #include "mtk_uni_stg_grid_2d.h"
00064
00065 namespace mtk {
00066
00067 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid2D &in) {
00068
00069     stream << '[' << in.west_bndy_ << ':' << in.num_cells_x_ << ':' <<
00070     in.east_bndy_ << " ] x ";
00071
00072     stream << '[' << in.south_bndy_ << ':' << in.num_cells_y_ << ':' <<
00073     in.north_bndy_ << " ] = " << std::endl << std::endl;
00074
00075     stream << "x:";

```

```

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

```

```

        discrete_domain_x_.size(),
00158         discrete_domain_x_.begin());
00159
00160     std::copy(grid.discrete_domain_y_.begin(),
00161             grid.discrete_domain_y_.begin() + grid.
discrete_domain_y_.size(),
00162             discrete_domain_y_.begin());
00163
00164     std::copy(grid.discrete_field_.begin(),
00165             grid.discrete_field_.begin() + grid.discrete_field_.size(),
00166             discrete_field_.begin());
00167 }
00168
00169 mtk::UniStgGrid2D::UniStgGrid2D(const Real &west_bndy,
00170                                 const Real &east_bndy,
00171                                 const int &num_cells_x,
00172                                 const Real &south_bndy,
00173                                 const Real &north_bndy,
00174                                 const int &num_cells_y,
00175                                 const mtk::FieldNature &nature) {
00176
00177     #if MTK_DEBUG_LEVEL > 0
00178     mtk::Tools::Prevent(west_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00179     mtk::Tools::Prevent(east_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00180     mtk::Tools::Prevent(east_bndy <= west_bndy, __FILE__, __LINE__, __func__);
00181     mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00182     mtk::Tools::Prevent(south_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00183     mtk::Tools::Prevent(north_bndy < mtk::kZero, __FILE__, __LINE__, __func__);
00184     mtk::Tools::Prevent(north_bndy <= south_bndy,
00185         __FILE__, __LINE__, __func__);
00186     mtk::Tools::Prevent(num_cells_y < 0, __FILE__, __LINE__, __func__);
00187     #endif
00188
00189     nature_ = nature;
00190
00191     west_bndy_ = west_bndy;
00192     east_bndy_ = east_bndy;
00193     num_cells_x_ = num_cells_x;
00194
00195     south_bndy_ = south_bndy;
00196     north_bndy_ = north_bndy;
00197     num_cells_y_ = num_cells_y;
00198
00199     delta_x_ = (east_bndy_ - west_bndy_) / ((mtk::Real) num_cells_x);
00200     delta_y_ = (north_bndy_ - south_bndy_) / ((mtk::Real) num_cells_y);
00201 }
00202
00203 mtk::UniStgGrid2D::~UniStgGrid2D() {}
00204
00205 mtk::FieldNature mtk::UniStgGrid2D::nature() const {
00206
00207     return nature_;
00208 }
00209
00210 mtk::Real mtk::UniStgGrid2D::west_bndy() const {
00211
00212     return west_bndy_;
00213 }
00214
00215 mtk::Real mtk::UniStgGrid2D::east_bndy() const {
00216
00217     return east_bndy_;
00218 }
00219
00220 int mtk::UniStgGrid2D::num_cells_x() const {
00221
00222     return num_cells_x_;
00223 }
00224
00225 mtk::Real mtk::UniStgGrid2D::delta_x() const {
00226
00227     return delta_x_;
00228 }
00229
00230 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_x() const
00231 {
00232     return discrete_domain_x_.data();
00233 }
00234
00235 mtk::Real mtk::UniStgGrid2D::south_bndy() const {

```

```

00236
00237     return south_bndy_;
00238 }
00239
00240 mtk::Real mtk::UniStgGrid2D::north_bndy() const {
00241
00242     return north_bndy_;
00243 }
00244
00245 int mtk::UniStgGrid2D::num_cells_y() const {
00246
00247     return num_cells_y_;
00248 }
00249
00250 mtk::Real mtk::UniStgGrid2D::delta_y() const {
00251
00252     return delta_y_;
00253 }
00254
00255 const mtk::Real* mtk::UniStgGrid2D::discrete_domain_y() const
00256 {
00257     return discrete_domain_y_.data();
00258 }
00259
00260 const mtk::Real* mtk::UniStgGrid2D::discrete_field() const {
00261
00262     return discrete_field_.data();
00263 }
00264
00265 void mtk::UniStgGrid2D::BindScalarField(Real (*ScalarField)(
Real xx, Real yy)) {
00266
00267     #if MTK_DEBUG_LEVEL > 0
00268     mtk::Tools::Prevent(nature_ != mtk::SCALAR, __FILE__, __LINE__, __func__);
00269     #endif
00270
00271
00272     discrete_domain_x_.reserve(num_cells_x_ + 2);
00273
00274     discrete_domain_x_.push_back(west_bndy_);
00275     #ifdef MTK_PRECISION_DOUBLE
00276     auto first_center = west_bndy_ + delta_x_/2.0;
00277     #else
00278     auto first_center = west_bndy_ + delta_x_/2.0f;
00279     #endif
00280     discrete_domain_x_.push_back(first_center);
00281     for (auto ii = 1; ii < num_cells_x_; ++ii) {
00282         discrete_domain_x_.push_back(first_center + ii*delta_x_);
00283     }
00284     discrete_domain_x_.push_back(east_bndy_);
00285
00286
00287     discrete_domain_y_.reserve(num_cells_y_ + 2);
00288
00289     discrete_domain_y_.push_back(south_bndy_);
00290     #ifdef MTK_PRECISION_DOUBLE
00291     first_center = south_bndy_ + delta_x_/2.0;
00292     #else
00293     first_center = south_bndy_ + delta_x_/2.0f;
00294     #endif
00295     discrete_domain_y_.push_back(first_center);
00296     for (auto ii = 1; ii < num_cells_y_; ++ii) {
00297         discrete_domain_y_.push_back(first_center + ii*delta_y_);
00298     }
00299     discrete_domain_y_.push_back(north_bndy_);
00300
00301
00302     discrete_field_.reserve((num_cells_x_ + 2)*(num_cells_y_ + 2));
00303
00304     for (int ii = 0; ii < num_cells_x_ + 2; ++ii) {
00305         for (int jj = 0; jj < num_cells_y_ + 2; ++jj) {
00306             discrete_field_.push_back(ScalarField(discrete_domain_x_[ii],
00307                                                     discrete_domain_y_[jj]));
00308         }
00309     }
00310
00311 }
00312 }
00313
00314
00315 void mtk::UniStgGrid2D::BindVectorFieldPComponent(
00316     mtk::Real (*VectorField)(mtk::Real xx, mtk::Real yy)) {
00317

```



```

00318 int mm{num_cells_x_};
00319 int nn{num_cells_y_};
00320
00321 int total{nn*(mm + 1) + mm*(nn + 1)};
00322
00323 #ifdef MTK_PRECISION_DOUBLE
00324 double half_delta_x{delta_x_/2.0};
00325 double half_delta_y{delta_y_/2.0};
00326 #else
00327 float half_delta_x{delta_x_/2.0f};
00328 float half_delta_y{delta_y_/2.0f};
00329 #endif
00330
00331 // We need every data point of the discrete domain; i.e. we need all the
00332 // nodes and all the centers. There are mm centers for the x direction, and
00333 // nn centers for the y direction. Since there is one node per center, that
00334 // amounts to 2*mm. If we finally consider the final boundary node, it
00335 // amounts to a total of 2*mm + 1 for the x direction. Analogously, for the
00336 // y direction, this amounts to 2*nn + 1.
00337
00338 discrete_domain_x_.reserve(2*mm + 1);
00339
00340 discrete_domain_x_.push_back(west_bndy_);
00341 for (int ii = 1; ii < (2*mm + 1); ++ii) {
00342     discrete_domain_x_.push_back(west_bndy_ + ii*half_delta_x);
00343 }
00344
00345 discrete_domain_y_.reserve(2*nn + 1);
00346
00347 discrete_domain_y_.push_back(south_bndy_);
00348 for (int ii = 1; ii < (2*nn + 1); ++ii) {
00349     discrete_domain_y_.push_back(south_bndy_ + ii*half_delta_y);
00350 }
00351
00352 discrete_field_.reserve(total);
00353
00354 // For each y-center.
00355 for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00356     // Bind all of the x-nodes for this y-center.
00357     for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00358         discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00359                                                 discrete_domain_y_[ii]));
00360
00361         #if MTK_DEBUG_LEVEL > 0
00362         std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00363             discrete_domain_y_[ii] << " = " <<
00364             VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00365         #endif
00366     }
00367 }
00368
00369 #if MTK_DEBUG_LEVEL > 0
00370 std::cout << std::endl;
00371 #endif
00372 }
00373
00374 void mtk::UniStgGrid2D::BindVectorFieldQComponent(
00375     mtk::Real (*VectorField)(mtk::Real xx, mtk::Real yy)) {
00376
00377     int mm{num_cells_x_};
00378     int nn{num_cells_y_};
00379
00380     // For each y-node.
00381     for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00382         // Bind all of the x-center for this y-node.
00383         for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00384             discrete_field_.push_back(VectorField(discrete_domain_x_[jj],
00385                                                     discrete_domain_y_[ii]));
00386
00387             #if MTK_DEBUG_LEVEL > 0
00388             std::cout << "Binding v at x = " << discrete_domain_x_[jj] << " y = " <<
00389                 discrete_domain_y_[ii] << " = " <<
00390                 VectorField(discrete_domain_x_[jj],discrete_domain_y_[ii]) << std::endl;
00391             #endif
00392         }
00393     }
00394 }

```

```

00403     #if MTK_DEBUG_LEVEL > 0
00404     std::cout << std::endl;
00405     #endif
00406 }
00407
00408 void mtk::UniStgGrid2D::BindVectorField(
00409     Real (*VectorFieldPComponent)(Real xx,Real yy),
00410     Real (*VectorFieldQComponent)(Real xx,Real yy)) {
00411
00412     #if MTK_DEBUG_LEVEL > 0
00413     mtk::Tools::Prevent(nature_ != mtk::VECTOR, __FILE__, __LINE__, __func__);
00414     #endif
00415
00416     BindVectorFieldPComponent(VectorFieldPComponent);
00417     BindVectorFieldQComponent(VectorFieldQComponent);
00418 }
00419
00420 bool mtk::UniStgGrid2D::WriteToFile(std::string filename,
00421     std::string space_name_x,
00422     std::string space_name_y,
00423     std::string field_name) const {
00424
00425     std::ofstream output_dat_file; // Output file.
00426
00427     output_dat_file.open(filename);
00428
00429     if (!output_dat_file.is_open()) {
00430         return false;
00431     }
00432
00433     if (nature_ == mtk::SCALAR) {
00434         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00435             field_name << std::endl;
00436
00437         for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00438             for (unsigned int jj = 0; jj < discrete_domain_y_.size(); ++jj) {
00439                 output_dat_file << discrete_domain_x_[ii] << ' ' <<
00440                     discrete_domain_y_[jj] << ' ' <<
00441                     discrete_field_[ii*discrete_domain_y_.size() + jj] <<
00442                     std::endl;
00443             }
00444             output_dat_file << std::endl;
00445         }
00446     } else {
00447         output_dat_file << "# " << space_name_x << ' ' << space_name_y << ' ' <<
00448             field_name << std::endl;
00449
00450         output_dat_file << "# Horizontal component:" << std::endl;
00451
00452         int mm{num_cells_x_};
00453         int nn{num_cells_y_};
00454
00455         // For each y-center.
00456         int idx{};
00457         for (int ii = 1; ii < 2*nn + 1; ii += 2) {
00458             // Bind all of the x-nodes for this y-center.
00459             for (int jj = 0; jj < 2*mm + 1; jj += 2) {
00460
00461                 output_dat_file << discrete_domain_x_[jj] << ' ' <<
00462                     discrete_domain_y_[ii] << ' ' << discrete_field_[idx] << ' ' <<
00463                     mtk::kZero << std::endl;
00464
00465                 ++idx;
00466             }
00467         }
00468
00469         int p_offset{nn*(mm + 1) - 1};
00470         idx = 0;
00471         output_dat_file << "# Vertical component:" << std::endl;
00472         // For each y-node.
00473         for (int ii = 0; ii < 2*nn + 1; ii += 2) {
00474             // Bind all of the x-center for this y-node.
00475             for (int jj = 1; jj < 2*mm + 1; jj += 2) {
00476
00477                 output_dat_file << discrete_domain_x_[jj] << ' ' <<
00478                     discrete_domain_y_[ii] << ' ' << mtk::kZero << ' ' <<
00479                     discrete_field_[p_offset + idx] << std::endl;
00480
00481                 ++idx;
00482             }
00483         }
00484     }
00485 }

```

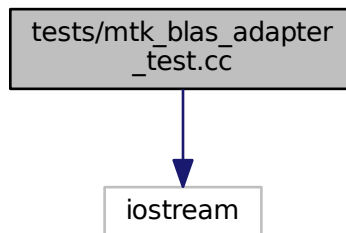
```
00486     }  
00487 }  
00488  
00489 output_dat_file.close();  
00490  
00491 return true;  
00492 }
```

17.87 tests/mtk_blas_adapter_test.cc File Reference

Test file for the [mtk::BLASAdapter](#) class.

```
#include <iostream>
```

Include dependency graph for mtk_blas_adapter_test.cc:



Functions

- int [main](#) ()

17.87.1 Detailed Description

Author

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

Definition in file [mtk_blas_adapter_test.cc](#).

17.87.2 Function Documentation

17.87.2.1 int main ()

Definition at line [109](#) of file [mtk_blas_adapter_test.cc](#).

17.88 mtk_blas_adapter_test.cc

```
00001
```

```

00008 /*
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00010 University. All rights reserved.
00011
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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
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00023
00024 3. Redistributions in binary form must reproduce the above copyright notice,
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00027
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
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     std::cout << "Testing mtk::BLASAdapter class." << std::endl;
00100     TestRealDenseMM();
00101 }
00102
00103 #else
00104 #include <iostream>
00105 using std::cout;
00106 using std::endl;
00107 int main () {
00108     cout << "This code HAS to be compiled with support for C++11." << endl;
00109     cout << "Exiting..." << endl;
00110 }
00111 #endif

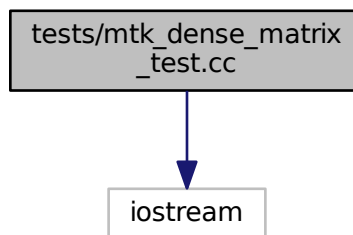
```

17.89 tests/mtk_dense_matrix_test.cc File Reference

Test file for the [mtk::DenseMatrix](#) class.

```
#include <iostream>
```

Include dependency graph for mtk_dense_matrix_test.cc:



Functions

- [int main \(\)](#)

17.89.1 Detailed Description

Author

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

Definition in file [mtk_dense_matrix_test.cc](#).

17.89.2 Function Documentation

17.89.2.1 int main ()

Definition at line 330 of file [mtk_dense_matrix_test.cc](#).

17.90 mtk_dense_matrix_test.cc

```

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00019 should be developed and included in any deliverable.
00020
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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructor() {
00062
00063     mtk::Tools::BeginUnitTestNo(1);
00064
00065     mtk::DenseMatrix m1;
00066
00067     mtk::Tools::EndUnitTestNo(1);
00068     mtk::Tools::Assert(m1.data() == nullptr);
00069 }
00070
00071 void TestConstructorWithNumRowsNumCols() {
00072
00073     mtk::Tools::BeginUnitTestNo(2);

```

```

00074
00075     int rr = 4;
00076     int cc = 7;
00077
00078     mtk::DenseMatrix m2(rr,cc);
00079
00080     mtk::Tools::EndUnitTestNo(2);
00081
00082     bool assertion =
00083         m2.data() != nullptr && m2.num_rows() == rr && m2.num_cols() == cc;
00084
00085     mtk::Tools::Assert(assertion);
00086 }
00087
00088 void TestConstructAsIdentity() {
00089
00090     mtk::Tools::BeginUnitTestNo(3);
00091
00092     int rank = 5;
00093     bool padded = true;
00094     bool transpose = false;
00095
00096     mtk::DenseMatrix m3(rank,padded,transpose);
00097
00098     mtk::DenseMatrix rr(rank + 2,rank);
00099
00100     for (int ii = 0; ii < rank; ++ii) {
00101         rr.SetValue(ii + 1, ii, mtk::kOne);
00102     }
00103
00104     mtk::Tools::EndUnitTestNo(3);
00105     mtk::Tools::Assert(m3 == rr);
00106 }
00107
00108 void TestConstructAsVandermonde() {
00109
00110     mtk::Tools::BeginUnitTestNo(4);
00111
00112     int rank = 5;
00113     bool padded = false;
00114     bool transpose = false;
00115
00116     mtk::DenseMatrix m4(rank,padded,transpose);
00117
00118     mtk::DenseMatrix rr(rank,rank);
00119
00120     for (int ii = 0; ii < rank; ++ii) {
00121         rr.SetValue(ii, ii, mtk::kOne);
00122     }
00123
00124     mtk::Tools::EndUnitTestNo(4);
00125     mtk::Tools::Assert(m4 == rr);
00126 }
00127
00128 void TestSetValueGetValue() {
00129
00130     mtk::Tools::BeginUnitTestNo(5);
00131
00132     int rr = 4;
00133     int cc = 7;
00134
00135     mtk::DenseMatrix m5(rr,cc);
00136
00137     for (auto ii = 0; ii < rr; ++ii) {
00138         for (auto jj = 0; jj < cc; ++jj) {
00139             m5.SetValue(ii,jj,(mtk::Real) ii + jj);
00140         }
00141     }
00142
00143     mtk::Real *vals = m5.data();
00144
00145     bool assertion{true};
00146
00147     for (auto ii = 0; ii < rr && assertion; ++ii) {
00148         for (auto jj = 0; jj < cc && assertion; ++jj) {
00149             assertion = assertion && m5.GetValue(ii,jj) == vals[ii*cc + jj];
00150         }
00151     }
00152
00153     mtk::Tools::EndUnitTestNo(5);
00154     mtk::Tools::Assert(assertion);

```

```

00155 }
00156
00157 void TestConstructAsVandermondeTranspose() {
00158
00159     mtk::Tools::BeginUnitTestNo(6);
00160
00161     bool transpose = false;
00162     int generator_length = 3;
00163     int progression_length = 4;
00164
00165     mtk::Real generator[] = {-0.5, 0.5, 1.5};
00166
00167     mtk::DenseMatrix m6(generator,generator_length,progression_length,transpose);
00168
00169     transpose = true;
00170
00171     mtk::DenseMatrix m7(generator,generator_length,progression_length,transpose);
00172     mtk::DenseMatrix rr(progression_length, generator_length);
00173
00174     rr.SetValue(0, 0, 1.0);
00175     rr.SetValue(0, 1, 1.0);
00176     rr.SetValue(0, 2, 1.0);
00177
00178     rr.SetValue(1, 0, -0.5);
00179     rr.SetValue(1, 1, 0.5);
00180     rr.SetValue(1, 2, 1.5);
00181
00182     rr.SetValue(2, 0, 0.25);
00183     rr.SetValue(2, 1, 0.25);
00184     rr.SetValue(2, 2, 2.25);
00185
00186     rr.SetValue(3, 0, -0.125);
00187     rr.SetValue(3, 1, 0.125);
00188     rr.SetValue(3, 2, 3.375);
00189
00190     mtk::Tools::EndUnitTestNo(6);
00191     mtk::Tools::Assert(m7 == rr);
00192 }
00193
00194 void TestKron() {
00195
00196     mtk::Tools::BeginUnitTestNo(7);
00197
00198     bool padded = false;
00199     bool transpose = false;
00200     int lots_of_rows = 2;
00201     int lots_of_cols = 5;
00202     mtk::DenseMatrix m8(lots_of_rows,padded,transpose);
00203
00204     mtk::DenseMatrix m9(lots_of_rows,lots_of_cols);
00205
00206     for (auto ii = 0; ii < lots_of_rows; ++ii) {
00207         for (auto jj = 0; jj < lots_of_cols; ++jj) {
00208             m9.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00209         }
00210     }
00211
00212     mtk::DenseMatrix m10 = mtk::DenseMatrix::Kron(m8,m9);
00213
00214     mtk::DenseMatrix rr(lots_of_rows*lots_of_rows, lots_of_rows*lots_of_cols);
00215
00216     rr.SetValue(0,0,1.0);
00217     rr.SetValue(0,1,2.0);
00218     rr.SetValue(0,2,3.0);
00219     rr.SetValue(0,3,4.0);
00220     rr.SetValue(0,4,5.0);
00221     rr.SetValue(0,5,0.0);
00222     rr.SetValue(0,6,0.0);
00223     rr.SetValue(0,7,0.0);
00224     rr.SetValue(0,8,0.0);
00225     rr.SetValue(0,9,0.0);
00226
00227     rr.SetValue(1,0,6.0);
00228     rr.SetValue(1,1,7.0);
00229     rr.SetValue(1,2,8.0);
00230     rr.SetValue(1,3,9.0);
00231     rr.SetValue(1,4,10.0);
00232     rr.SetValue(1,5,0.0);
00233     rr.SetValue(1,6,0.0);
00234     rr.SetValue(1,7,0.0);
00235     rr.SetValue(1,8,0.0);

```



```

00236 rr.SetValue(1,9,0.0);
00237
00238 rr.SetValue(2,0,0.0);
00239 rr.SetValue(2,1,0.0);
00240 rr.SetValue(2,2,0.0);
00241 rr.SetValue(2,3,0.0);
00242 rr.SetValue(2,4,0.0);
00243 rr.SetValue(2,5,1.0);
00244 rr.SetValue(2,6,2.0);
00245 rr.SetValue(2,7,3.0);
00246 rr.SetValue(2,8,4.0);
00247 rr.SetValue(2,9,5.0);
00248
00249 rr.SetValue(3,0,0.0);
00250 rr.SetValue(3,1,0.0);
00251 rr.SetValue(3,2,0.0);
00252 rr.SetValue(3,3,0.0);
00253 rr.SetValue(3,4,0.0);
00254 rr.SetValue(3,5,6.0);
00255 rr.SetValue(3,6,7.0);
00256 rr.SetValue(3,7,8.0);
00257 rr.SetValue(3,8,9.0);
00258 rr.SetValue(3,9,10.0);
00259
00260 mtk::Tools::EndUnitTestNo(7);
00261 mtk::Tools::Assert(m10 == rr);
00262 }
00263
00264 void TestConstructWithNumRowsNumColsAssignmentOperator() {
00265
00266     mtk::Tools::BeginUnitTestNo(8);
00267
00268     int lots_of_rows = 4;
00269     int lots_of_cols = 3;
00270     mtk::DenseMatrix m11(lots_of_rows,lots_of_cols);
00271
00272     for (auto ii = 0; ii < lots_of_rows; ++ii) {
00273         for (auto jj = 0; jj < lots_of_cols; ++jj) {
00274             m11.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00275         }
00276     }
00277
00278     m11.Transpose();
00279
00280     mtk::DenseMatrix m12;
00281
00282     m12 = m11;
00283
00284     mtk::Tools::EndUnitTestNo(8);
00285     mtk::Tools::Assert(m11 == m12);
00286 }
00287
00288 void TestConstructAsVandermondeTransposeAssignmentOperator() {
00289
00290     mtk::Tools::BeginUnitTestNo(9);
00291
00292     bool transpose = false;
00293     int gg_l = 3;
00294     int progression_length = 4;
00295     mtk::Real gg[] = {-0.5, 0.5, 1.5};
00296
00297     mtk::DenseMatrix m13(gg, gg_l ,progression_length, transpose);
00298
00299     mtk::DenseMatrix m14;
00300
00301     m14 = m13;
00302
00303     m13.Transpose();
00304
00305     m14 = m13;
00306
00307     mtk::Tools::EndUnitTestNo(9);
00308     mtk::Tools::Assert(m13 == m14);
00309 }
00310
00311 int main () {
00312
00313     std::cout << "Testing mtk::DenseMatrix class." << std::endl;
00314
00315     TestDefaultConstructor();
00316     TestConstructorWithNumRowsNumCols();

```

```

00317 TestConstructAsIdentity();
00318 TestConstructAsVandermonde();
00319 TestSetValueGetValue();
00320 TestConstructAsVandermondeTranspose();
00321 TestKron();
00322 TestConstructWithNumRowsNumColsAssignmentOperator();
00323 TestConstructAsVandermondeTransposeAssignmentOperator();
00324 }
00325
00326 #else
00327 #include <iostream>
00328 using std::cout;
00329 using std::endl;
00330 int main () {
00331     cout << "This code HAS to be compiled with support for C++11." << endl;
00332     cout << "Exiting..." << endl;
00333 }
00334 #endif

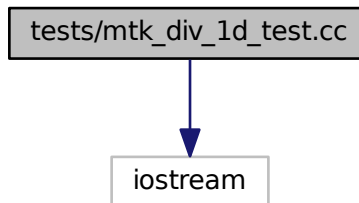
```

17.91 tests/mtk_div_1d_test.cc File Reference

Testing the mimetic 1D divergence, constructed with the CBS algorithm.

```
#include <iostream>
```

Include dependency graph for mtk_div_1d_test.cc:



Functions

- int [main](#) ()

17.91.1 Detailed Description

Author

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

Definition in file [mtk_div_1d_test.cc](#).

17.91.2 Function Documentation

17.91.2.1 int main ()

Definition at line 288 of file [mtk_div_1d_test.cc](#).

17.92 mtk_div_1d_test.cc

```

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00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <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     mtk::Tools::BeginUnitTestNo(9);
00246
00247     mtk::Div1D div4;
00248
00249     bool assertion = div4.ConstructDiv1D(4);
00250
00251     if (!assertion) {
00252         std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00253     }
00254
00255     std::cout << div4 << std::endl;
00256
00257     mtk::UniStgGrid1D grid(0.0, 1.0, 11);
00258
00259     std::cout << grid << std::endl;
00260
00261     mtk::DenseMatrix div4m(div4.ReturnAsDenseMatrix(grid));
00262
00263     std::cout << div4m << std::endl;
00264
00265     mtk::Tools::EndUnitTestNo(9);
00266 }
00267
00268 int main () {
00269     std::cout << "Testing mtk::Div1D class." << std::endl;
00270
00271     TestDefaultConstructorFactoryMethodDefault();
00272     TestDefaultConstructorFactoryMethodFourthOrder();
00273     TestDefaultConstructorFactoryMethodSixthOrder();
00274     TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00275     TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00276     TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();
00277     TestDefaultConstructorFactoryMethodFourteenthOrderDefThreshold();
00278     TestSecondOrderReturnAsDenseMatrixWithGrid();
00279     TestFourthOrderReturnAsDenseMatrixWithGrid();
00280 }
00281
00282 #else
00283 #include <iostream>
00284 using std::cout;
00285 using std::endl;
00286 int main () {
00287     cout << "This code HAS to be compiled with support for C++11." << endl;
00288     cout << "Exiting..." << endl;
00289 }
00290 #endif

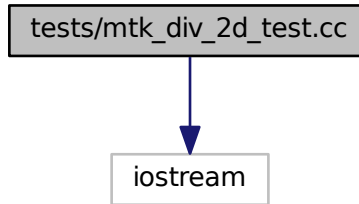
```

17.93 tests/mtk_div_2d_test.cc File Reference

Test file for the `mtk::Div2D` class.

```
#include <iostream>
```

Include dependency graph for mtk_div_2d_test.cc:



Functions

- int [main](#) ()

17.93.1 Detailed Description

Author

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

Definition in file [mtk_div_2d_test.cc](#).

17.93.2 Function Documentation

17.93.2.1 int main ()

Definition at line [139](#) of file [mtk_div_2d_test.cc](#).

17.94 mtk_div_2d_test.cc

```

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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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00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055 #include <cmath>
00056 #include <ctime>
00057 #include <iostream>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructorFactory() {
00062
00063     mtk::Tools::BeginUnitTestNo(1);
00064
00065     mtk::Div2D dd;
00066
00067     mtk::Real aa = 0.0;
00068     mtk::Real bb = 1.0;
00069     mtk::Real cc = 0.0;
00070     mtk::Real ee = 1.0;
00071
00072     int nn = 5;
00073     int mm = 5;
00074
00075     mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00076
00077     bool assertion = dd.ConstructDiv2D(ddg);
00078
00079     if (!assertion) {
00080         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00081     }
00082
00083     mtk::Tools::EndUnitTestNo(1);
00084     mtk::Tools::Assert(assertion);
00085 }
00086
00087 void TestReturnAsDenseMatrixWriteToFile() {
00088
00089     mtk::Tools::BeginUnitTestNo(2);
00090
00091     mtk::Div2D dd;
00092
00093     mtk::Real aa = 0.0;
00094     mtk::Real bb = 1.0;
00095     mtk::Real cc = 0.0;
00096     mtk::Real ee = 1.0;
00097
00098     int nn = 5;
00099     int mm = 5;
00100
00101     mtk::UniStgGrid2D ddg(aa, bb, nn, cc, ee, mm);
00102
00103     bool assertion = dd.ConstructDiv2D(ddg);
00104
00105

```



```

00106
00107     if (!assertion) {
00108         std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00109     }
00110
00111     mtk::DenseMatrix ddm(dd.ReturnAsDenseMatrix());
00112
00113     assertion = assertion && (ddm.num_rows() != mtk::kZero);
00114
00115     std::cout << ddm << std::endl;
00116
00117     assertion = assertion && ddm.WriteToFile("mtk_div_2d_test_02.dat");
00118
00119     if (!assertion) {
00120         std::cerr << "Error writing to file." << std::endl;
00121     }
00122
00123     mtk::Tools::EndUnitTestNo(2);
00124     mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129     std::cout << "Testing mtk::Div2D class." << std::endl;
00130
00131     TestDefaultConstructorFactory();
00132     TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140     cout << "This code HAS to be compiled with support for C++11." << endl;
00141     cout << "Exiting..." << endl;
00142 }
00143 #endif

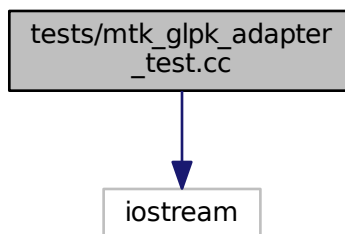
```

17.95 tests/mtk_glpk_adapter_test.cc File Reference

Test file for the [mtk::GLPKAdapter](#) class.

```
#include <iostream>
```

Include dependency graph for `mtk_glpk_adapter_test.cc`:



Functions

- `int main ()`

17.95.1 Detailed Description

Author

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

Todo Test the `mtk::GLPKAdapter` class.

Definition in file `mtk_glpk_adapter_test.cc`.

17.95.2 Function Documentation

17.95.2.1 `int main ()`

Definition at line 81 of file `mtk_glpk_adapter_test.cc`.

17.96 `mtk_glpk_adapter_test.cc`

```

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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.
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00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>

```

```

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

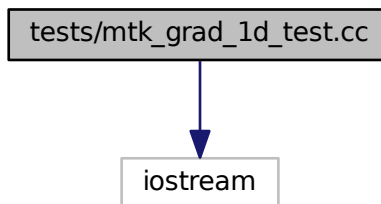
```

17.97 tests/mtk_grad_1d_test.cc File Reference

Testing the mimetic 1D gradient, constructed with the CBS algorithm.

```
#include <iostream>
```

Include dependency graph for mtk_grad_1d_test.cc:



Functions

- int `main` ()

17.97.1 Detailed Description

Author

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

Definition in file [mtk_grad_1d_test.cc](#).

17.97.2 Function Documentation

17.97.2.1 int main ()

Definition at line 296 of file [mtk_grad_1d_test.cc](#).

17.98 mtk_grad_1d_test.cc

```

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00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
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     std::cout << grad2 << std::endl;
00073

```

```

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,-1.666667);
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(5,4,1.666667);
00223     ref.SetValue(5,5,-15.0);
00224     ref.SetValue(5,6,13.3333);
00225
00226     mtk::Tools::EndUnitTestNo(6);
00227     mtk::Tools::Assert(grad2m == ref);
00228 }
00229
00230 void TestReturnAsDimensionlessDenseMatrix() {
00231
00232     mtk::Tools::BeginUnitTestNo(7);
00233
00234     mtk::Grad1D grad4;
00235

```

```

00236     bool assertion = grad4.ConstructGrad1D(4);
00237
00238     if (!assertion) {
00239         std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00240     }
00241
00242     mtk::DenseMatrix grad4m(grad4.ReturnAsDimensionlessDenseMatrix
00243                               (10));
00244
00245     std::cout << grad4m << std::endl;
00246
00247     mtk::Tools::EndUnitTestNo(7);
00248     mtk::Tools::Assert(assertion);
00249 }
00250 void TestWriteToFile() {
00251
00252     mtk::Tools::BeginUnitTestNo(8);
00253
00254     mtk::Grad1D grad2;
00255
00256     bool assertion = grad2.ConstructGrad1D();
00257
00258     if (!assertion) {
00259         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00260     }
00261
00262     mtk::UniStgGrid1D grid(0.0, 1.0, 50);
00263
00264     mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00265
00266     std::cout << grad2m << std::endl;
00267
00268     assertion = assertion && grad2m.WriteToFile("mtk_grad_1d_test_08.dat");
00269
00270     if(!assertion) {
00271         std::cerr << "Error writing to file." << std::endl;
00272     }
00273
00274     mtk::Tools::EndUnitTestNo(8);
00275     mtk::Tools::Assert(assertion);
00276 }
00277
00278 int main () {
00279
00280     std::cout << "Testing mtk::Grad1D class." << std::endl;
00281
00282     TestDefaultConstructorFactoryMethodDefault();
00283     TestDefaultConstructorFactoryMethodFourthOrder();
00284     TestDefaultConstructorFactoryMethodSixthOrder();
00285     TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00286     TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00287     TestReturnAsDenseMatrixWithGrid();
00288     TestReturnAsDimensionlessDenseMatrix();
00289     TestWriteToFile();
00290 }
00291
00292 #else
00293 #include <iostream>
00294 using std::cout;
00295 using std::endl;
00296 int main () {
00297     cout << "This code HAS to be compiled with support for C++11." << endl;
00298     cout << "Exiting..." << endl;
00299 }
00300 #endif

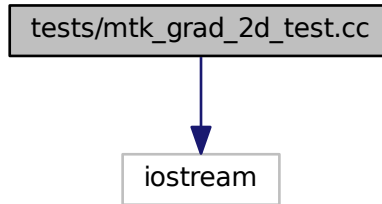
```

17.99 tests/mtk_grad_2d_test.cc File Reference

Test file for the `mtk::Grad2D` class.

```
#include <iostream>
```

Include dependency graph for `mtk_grad_2d_test.cc`:



Functions

- `int main ()`

17.99.1 Detailed Description

Author

: Eduardo J. Sanchez (ejspeiro) - [esanchez at mail dot sdsu dot edu](mailto:esanchez@mail.sdsu.edu)

Definition in file [mtk_grad_2d_test.cc](#).

17.99.2 Function Documentation

17.99.2.1 `int main ()`

Definition at line [139](#) of file [mtk_grad_2d_test.cc](#).

17.100 `mtk_grad_2d_test.cc`

```

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00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00019 should be developed and included in any deliverable.
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00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```



```

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00052 */
00053
00054 #if __cplusplus == 201103L
00055 #include <cmath>
00056 #include <ctime>
00057 #include <iostream>
00058 #include "mtk.h"
00059
00060 void TestDefaultConstructorFactory() {
00061     mtk::Tools::BeginUnitTestNo(1);
00062
00063     mtk::Grad2D gg;
00064
00065     mtk::Real aa = 0.0;
00066     mtk::Real bb = 1.0;
00067     mtk::Real cc = 0.0;
00068     mtk::Real dd = 1.0;
00069
00070     int nn = 5;
00071     int mm = 5;
00072
00073     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00074
00075     bool assertion = gg.ConstructGrad2D(ggg);
00076
00077     if (!assertion) {
00078         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00079     }
00080
00081     mtk::Tools::EndUnitTestNo(1);
00082     mtk::Tools::Assert(assertion);
00083 }
00084
00085 void TestReturnAsDenseMatrixWriteToFile() {
00086     mtk::Tools::BeginUnitTestNo(2);
00087
00088     mtk::Grad2D gg;
00089
00090     mtk::Real aa = 0.0;
00091     mtk::Real bb = 1.0;
00092     mtk::Real cc = 0.0;
00093     mtk::Real dd = 1.0;
00094
00095     int nn = 5;
00096     int mm = 5;
00097
00098     mtk::UniStgGrid2D ggg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00099
00100     bool assertion = gg.ConstructGrad2D(ggg);

```

```

00106
00107     if (!assertion) {
00108         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00109     }
00110
00111     mtk::DenseMatrix ggm(gg.ReturnAsDenseMatrix());
00112
00113     assertion = assertion && (ggm.num_rows() != mtk::kZero);
00114
00115     std::cout << ggm << std::endl;
00116
00117     assertion = assertion && ggm.WriteToFile("mtk_grad_2d_test_02.dat");
00118
00119     if (!assertion) {
00120         std::cerr << "Error writing to file." << std::endl;
00121     }
00122
00123     mtk::Tools::EndUnitTestNo(2);
00124     mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129     std::cout << "Testing mtk::Grad2D class." << std::endl;
00130
00131     TestDefaultConstructorFactory();
00132     TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140     cout << "This code HAS to be compiled with support for C++11." << endl;
00141     cout << "Exiting..." << endl;
00142 }
00143 #endif

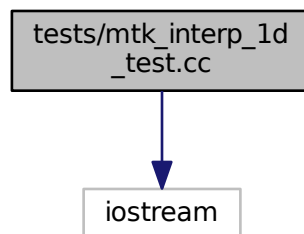
```

17.101 tests/mtk_interp_1d_test.cc File Reference

Testing the 1D interpolation.

```
#include <iostream>
```

Include dependency graph for mtk_interp_1d_test.cc:



Functions

- int [main](#) ()

17.101.1 Detailed Description

Author

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

Definition in file [mtk_interp_1d_test.cc](#).

17.101.2 Function Documentation

17.101.2.1 int main ()

Definition at line 113 of file [mtk_interp_1d_test.cc](#).

17.102 mtk_interp_1d_test.cc

```
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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
```

```

00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064     mtk::Tools::BeginUnitTestNo(1);
00065
00066     mtk::Interp1D inter;
00067
00068     bool assertion = inter.ConstructInterp1D();
00069
00070     if (!assertion) {
00071         std::cerr << "Mimetic interp could not be built." << std::endl;
00072     }
00073
00074     mtk::Tools::EndUnitTestNo(1);
00075     mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestReturnAsDenseMatrixWithGrid() {
00079
00080     mtk::Tools::BeginUnitTestNo(2);
00081
00082     mtk::Interp1D inter;
00083
00084     bool assertion = inter.ConstructInterp1D();
00085
00086     if (!assertion) {
00087         std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00088     }
00089
00090     mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00091
00092     mtk::DenseMatrix interpm(inter.ReturnAsDenseMatrix(grid));
00093
00094     assertion =
00095         assertion && interpm.GetValue(0,0) == 1.0 && interpm.GetValue(5,6) == 1.0;
00096
00097     mtk::Tools::EndUnitTestNo(2);
00098     mtk::Tools::Assert(assertion);
00099 }
00100
00101 int main () {
00102
00103     std::cout << "Testing mtk::Interp1D class." << std::endl;
00104
00105     TestDefaultConstructorFactoryMethodDefault();
00106     TestReturnAsDenseMatrixWithGrid();
00107 }
00108
00109 #else
00110 #include <iostream>
00111 using std::cout;
00112 using std::endl;
00113 int main () {
00114     cout << "This code HAS to be compiled with support for C++11." << endl;
00115     cout << "Exiting..." << endl;
00116 }
00117 #endif

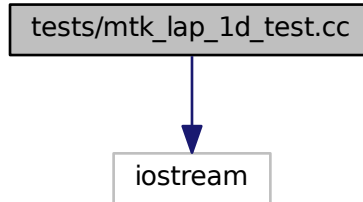
```

17.103 tests/mtk_lap_1d_test.cc File Reference

Testing the 1D Laplacian operator.

```
#include <iostream>
```

Include dependency graph for mtk_lap_1d_test.cc:



Functions

- int [main](#) ()

17.103.1 Detailed Description

Author

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

Definition in file [mtk_lap_1d_test.cc](#).

17.103.2 Function Documentation

17.103.2.1 int main ()

Definition at line [193](#) of file [mtk_lap_1d_test.cc](#).

17.104 mtk_lap_1d_test.cc

```

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00018 and a copy of the modified files should be reported once modifications are
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00020 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
00021 should be developed and included in any deliverable.
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00023 2. Redistributions of source code must be done through direct
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00025

```

```

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00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059
00060 #include "mtk.h"
00061
00062 void TestDefaultConstructorFactoryMethodDefault() {
00063
00064     mtk::Tools::BeginUnitTestNo(1);
00065
00066     mtk::Lap1D lap2;
00067
00068     bool assertion = lap2.ConstructLap1D();
00069
00070     if (!assertion) {
00071         std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00072     }
00073
00074     mtk::Tools::EndUnitTestNo(1);
00075     mtk::Tools::Assert(assertion);
00076 }
00077
00078 void TestDefaultConstructorFactoryMethodFourthOrder() {
00079
00080     mtk::Tools::BeginUnitTestNo(2);
00081
00082     mtk::Lap1D lap4;
00083
00084     bool assertion = lap4.ConstructLap1D(4);
00085
00086     if (!assertion) {
00087         std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00088     }
00089
00090     mtk::Tools::EndUnitTestNo(2);
00091     mtk::Tools::Assert(assertion);
00092 }
00093
00094 void TestDefaultConstructorFactoryMethodSixthOrder() {
00095
00096     mtk::Tools::BeginUnitTestNo(3);
00097
00098     mtk::Lap1D lap6;
00099
00100     bool assertion = lap6.ConstructLap1D(6);
00101
00102     if (!assertion) {
00103         std::cerr << "Mimetic lap (6th order) could not be built." << std::endl;
00104     }
00105
00106     mtk::Tools::EndUnitTestNo(3);

```

```

00107     mtk::Tools::Assert(assertion);
00108 }
00109
00110 void TestDefaultConstructorFactoryMethodEightOrderDefThreshold() {
00111
00112     mtk::Tools::BeginUnitTestNo(4);
00113
00114     mtk::Lap1D lap8;
00115
00116     bool assertion = lap8.ConstructLap1D(8);
00117
00118     if (!assertion) {
00119         std::cerr << "Mimetic lap (8th order) could not be built." << std::endl;
00120     }
00121
00122     mtk::Tools::EndUnitTestNo(4);
00123 }
00124
00125 void TestDefaultConstructorFactoryMethodTenthOrderDefThreshold() {
00126
00127     mtk::Tools::BeginUnitTestNo(5);
00128
00129     mtk::Lap1D lap10;
00130
00131     bool assertion = lap10.ConstructLap1D(10);
00132
00133     if (!assertion) {
00134         std::cerr << "Mimetic lap (10th order) could not be built." << std::endl;
00135     }
00136
00137     mtk::Tools::EndUnitTestNo(5);
00138 }
00139
00140 void TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold() {
00141
00142     mtk::Tools::BeginUnitTestNo(6);
00143
00144     mtk::Lap1D lap12;
00145
00146     bool assertion = lap12.ConstructLap1D(12);
00147
00148     if (!assertion) {
00149         std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00150     }
00151
00152     mtk::Tools::EndUnitTestNo(6);
00153 }
00154
00155 void TestReturnAsDenseMatrix() {
00156
00157     mtk::Tools::BeginUnitTestNo(8);
00158
00159     mtk::Lap1D lap4;
00160
00161     bool assertion = lap4.ConstructLap1D(4);
00162
00163     if (!assertion) {
00164         std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00165     }
00166
00167     mtk::UniStgGrid1D aux(0.0, 1.0, 11);
00168
00169     mtk::DenseMatrix lap4_m(lap4.ReturnAsDenseMatrix(aux));
00170
00171     assertion = assertion &&
00172         abs(lap4_m.GetValue(1, 0) - 385.133) < mtk::kDefaultTolerance &&
00173         abs(lap4_m.GetValue(11, 12) - 385.133) < mtk::kDefaultTolerance;
00174     mtk::Tools::EndUnitTestNo(8);
00175     mtk::Tools::Assert(assertion);
00176 }
00177
00178 int main () {
00179
00180     std::cout << "Testing MTK 1D Laplacian" << std::endl;
00181
00182     TestDefaultConstructorFactoryMethodDefault();
00183     TestDefaultConstructorFactoryMethodFourthOrder();
00184     TestDefaultConstructorFactoryMethodSixthOrder();
00185     TestDefaultConstructorFactoryMethodEightOrderDefThreshold();
00186     TestDefaultConstructorFactoryMethodTenthOrderDefThreshold();
00187     TestDefaultConstructorFactoryMethodTwelfthOrderDefThreshold();

```

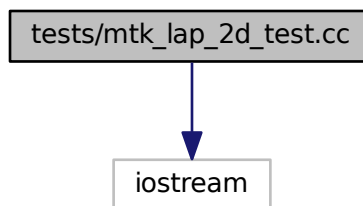
```
00188     TestReturnAsDenseMatrix();
00189 }
00190
00191 #else
00192 #include <iostream>
00193 int main () {
00194     std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00195     std::cout << "Exiting..." << std::endl;
00196 }
00197 #endif
```

17.105 tests/mtk_lap_2d_test.cc File Reference

Test file for the [mtk::Lap2D](#) class.

```
#include <iostream>
```

Include dependency graph for `mtk_lap_2d_test.cc`:



Functions

- `int main ()`

17.105.1 Detailed Description

Author

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

Definition in file [mtk_lap_2d_test.cc](#).

17.105.2 Function Documentation

17.105.2.1 `int main ()`

Definition at line [139](#) of file [mtk_lap_2d_test.cc](#).

17.106 mtk_lap_2d_test.cc

```

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00017 completed, unless these modifications are made through the project's GitHub
00018 page: http://www.csrc.sdsu.edu/mtk. Documentation related to said modifications
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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructorFactory() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::Lap2D ll;
00068
00069     mtk::Real aa = 0.0;
00070     mtk::Real bb = 1.0;
00071     mtk::Real cc = 0.0;
00072     mtk::Real dd = 1.0;
00073
00074     int nn = 5;
00075     int mm = 5;
00076
00077     mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00078
00079     bool assertion = ll.ConstructLap2D(llg);
00080
00081     if (!assertion) {
00082         std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00083     }
00084

```

```

00085     mtk::Tools::EndUnitTestNo(1);
00086     mtk::Tools::Assert(assertion);
00087 }
00088
00089 void TestReturnAsDenseMatrixWriteToFile() {
00090
00091     mtk::Tools::BeginUnitTestNo(2);
00092
00093     mtk::Lap2D ll;
00094
00095     mtk::Real aa = 0.0;
00096     mtk::Real bb = 1.0;
00097     mtk::Real cc = 0.0;
00098     mtk::Real dd = 1.0;
00099
00100     int nn = 5;
00101     int mm = 5;
00102
00103     mtk::UniStgGrid2D llg(aa, bb, nn, cc, dd, mm);
00104
00105     bool assertion = ll.ConstructLap2D(llg);
00106
00107     if (!assertion) {
00108         std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00109     }
00110
00111     mtk::DenseMatrix llm(ll.ReturnAsDenseMatrix());
00112
00113     assertion = assertion && (llm.num_rows() != mtk::kZero);
00114
00115     std::cout << llm << std::endl;
00116
00117     assertion = assertion && llm.WriteToFile("mtk_lap_2d_test_02.dat");
00118
00119     if (!assertion) {
00120         std::cerr << "Error writing to file." << std::endl;
00121     }
00122
00123     mtk::Tools::EndUnitTestNo(2);
00124     mtk::Tools::Assert(assertion);
00125 }
00126
00127 int main () {
00128
00129     std::cout << "Testing mtk::Lap2D class." << std::endl;
00130
00131     TestDefaultConstructorFactory();
00132     TestReturnAsDenseMatrixWriteToFile();
00133 }
00134
00135 #else
00136 #include <iostream>
00137 using std::cout;
00138 using std::endl;
00139 int main () {
00140     cout << "This code HAS to be compiled with support for C++11." << endl;
00141     cout << "Exiting..." << endl;
00142 }
00143 #endif

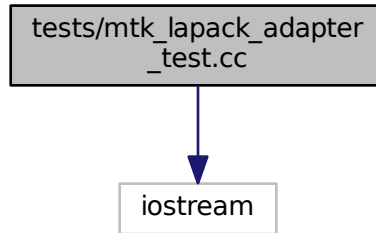
```

17.107 tests/mtk_lapack_adapter_test.cc File Reference

Test file for the [mtk::LAPACKAdapter](#) class.

```
#include <iostream>
```

Include dependency graph for mtk_lapack_adapter_test.cc:



Functions

- int [main](#) ()

17.107.1 Detailed Description

Author

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

Todo Test the [mtk::LAPACKAdapter](#) class.

Definition in file [mtk_lapack_adapter_test.cc](#).

17.107.2 Function Documentation

17.107.2.1 int main ()

Definition at line [81](#) of file [mtk_lapack_adapter_test.cc](#).

17.108 mtk_lapack_adapter_test.cc

```
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00021 should be developed and included in any deliverable.
```

```

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00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::Tools::EndUnitTestNo(1);
00068 }
00069
00070 int main () {
00071
00072     std::cout << "Testing mtk::LAPACKAdapter class." << std::endl;
00073
00074     Test1();
00075 }
00076
00077 #else
00078 #include <iostream>
00079 using std::cout;
00080 using std::endl;
00081 int main () {
00082     cout << "This code HAS to be compiled with support for C++11." << endl;
00083     cout << "Exiting..." << endl;
00084 }
00085 #endif

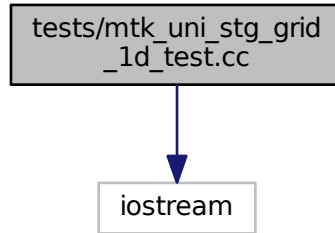
```

17.109 tests/mtk_uni_stg_grid_1d_test.cc File Reference

Test file for the `mtk::UniStgGrid1D` class.

```
#include <iostream>
```

Include dependency graph for mtk_uni_stg_grid_1d_test.cc:



Functions

- int [main](#) ()

17.109.1 Detailed Description

Author

: Eduardo J. Sanchez (ejspeiro) - [esanchez at mail dot sdsu dot edu](mailto:esanchez@mail.sdsu.edu)

Definition in file [mtk_uni_stg_grid_1d_test.cc](#).

17.109.2 Function Documentation

17.109.2.1 int main ()

Definition at line [172](#) of file [mtk_uni_stg_grid_1d_test.cc](#).

17.110 mtk_uni_stg_grid_1d_test.cc

```
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```

```

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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void TestDefaultConstructor() {
00062
00063     mtk::Tools::BeginUnitTestNo(1);
00064
00065     mtk::UniStgGrid1D gg;
00066
00067     mtk::Tools::EndUnitTestNo(1);
00068     mtk::Tools::Assert(gg.delta_x() == mtk::kZero);
00069 }
00070
00071 mtk::Real ScalarField(mtk::Real xx) {
00072
00073     return 2.0*xx;
00074 }
00075
00076 void TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField() {
00077
00078     mtk::Tools::BeginUnitTestNo(2);
00079
00080     mtk::Real aa = 0.0;
00081     mtk::Real bb = 1.0;
00082
00083     int nn = 5;
00084
00085     mtk::UniStgGrid1D gg(aa, bb, nn);
00086
00087     gg.BindScalarField(ScalarField);
00088
00089     std::cout << gg << std::endl;
00090
00091     mtk::Tools::EndUnitTestNo(2);
00092     mtk::Tools::Assert(gg.delta_x() == 0.2 && gg.
num_cells_x() == 5);
00093 }
00094
00095 void TestBindScalarFieldWriteToFile() {
00096
00097     mtk::Tools::BeginUnitTestNo(3);
00098
00099     mtk::Real aa = 0.0;
00100     mtk::Real bb = 1.0;
00101
00102     int nn = 5;
00103

```

```

00104     mtk::UniStgGrid1D gg(aa, bb, nn);
00105
00106     bool assertion{true};
00107
00108     gg.BindScalarField(ScalarField);
00109
00110     assertion =
00111         assertion &&
00112         gg.discrete_field_u()[0] == 0.0 &&
00113         gg.discrete_field_u()[gg.num_cells_x() + 2 - 1] == 2.0;
00114
00115     if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_03.dat", "x", "u(x)")) {
00116         std::cerr << "Error writing to file." << std::endl;
00117         assertion = false;
00118     }
00119
00120     mtk::Tools::EndUnitTestNo(3);
00121     mtk::Tools::Assert(assertion);
00122 }
00123
00124 mtk::Real VectorFieldPComponent(mtk::Real xx) {
00125     return xx*xx;
00126 }
00127
00128 void TestBindVectorField() {
00129
00130     mtk::Tools::BeginUnitTestNo(4);
00131
00132     mtk::Real aa = 0.0;
00133     mtk::Real bb = 1.0;
00134
00135     int nn = 20;
00136
00137     mtk::UniStgGrid1D gg(aa, bb, nn, mtk::VECTOR);
00138
00139     bool assertion{true};
00140
00141     gg.BindVectorField(VectorFieldPComponent);
00142
00143     assertion =
00144         assertion &&
00145         gg.discrete_field_u()[0] == 0.0 &&
00146         gg.discrete_field_u()[gg.num_cells_x() + 1 - 1] == 1.0;
00147
00148     if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_04.dat", "x", "v(x)")) {
00149         std::cerr << "Error writing to file." << std::endl;
00150         assertion = false;
00151     }
00152
00153     mtk::Tools::EndUnitTestNo(4);
00154     mtk::Tools::Assert(assertion);
00155 }
00156
00157 int main () {
00158     std::cout << "Testing mtk::UniStgGrid1D class." << std::endl;
00159
00160     TestDefaultConstructor();
00161     TestConstructWithWestBndyEastBndyNumCellsOStreamOperatorBindScalarField();
00162     TestBindScalarFieldWriteToFile();
00163     TestBindVectorField();
00164 }
00165
00166 #else
00167 #include <iostream>
00168 using std::cout;
00169 using std::endl;
00170 int main () {
00171     cout << "This code HAS to be compiled with support for C++11." << endl;
00172     cout << "Exiting..." << endl;
00173 }
00174 #endif

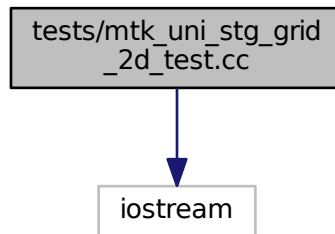
```

17.111 tests/mtk_uni_stg_grid_2d_test.cc File Reference

Test file for the [mtk::UniStgGrid2D](#) class.

```
#include <iostream>
```

Include dependency graph for `mtk_uni_stg_grid_2d_test.cc`:



Functions

- `int` [main](#) ()

17.111.1 Detailed Description

Author

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

Definition in file [mtk_uni_stg_grid_2d_test.cc](#).

17.111.2 Function Documentation

17.111.2.1 `int main ()`

Definition at line [202](#) of file [mtk_uni_stg_grid_2d_test.cc](#).

17.112 mtk_uni_stg_grid_2d_test.cc

```
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```

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00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <cmath>
00057 #include <ctime>
00058
00059 #include <iostream>
00060
00061 #include "mtk.h"
00062
00063 void TestDefaultConstructor() {
00064
00065     mtk::Tools::BeginUnitTestNo(1);
00066
00067     mtk::UniStgGrid2D gg;
00068
00069     mtk::Tools::EndUnitTestNo(1);
00070     mtk::Tools::Assert(gg.delta_x() == mtk::kZero && gg.
00071     delta_y() == mtk::kZero);
00072 }
00073
00074 void
00075 TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOSTreamOperator() {
00076
00077     mtk::Tools::BeginUnitTestNo(2);
00078
00079     mtk::Real aa = 0.0;
00080     mtk::Real bb = 1.0;
00081     mtk::Real cc = 0.0;
00082     mtk::Real dd = 1.0;
00083
00084     int nn = 5;
00085     int mm = 7;
00086
00087     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00088
00089     std::cout << gg << std::endl;
00090
00091     mtk::Tools::EndUnitTestNo(2);
00092     mtk::Tools::Assert(gg.delta_x() == 0.2 &&
00093     abs(gg.delta_y() - 0.142857) <
00094     mtk::kDefaultTolerance);
00095 }
00096
00097 void TestGetters() {
00098

```

```

00097     mtk::Tools::BeginUnitTestNo(3);
00098
00099     mtk::Real aa = 0.0;
00100     mtk::Real bb = 1.0;
00101     mtk::Real cc = 0.0;
00102     mtk::Real dd = 1.0;
00103
00104     int nn = 5;
00105     int mm = 7;
00106
00107     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00108
00109     bool assertion{true};
00110
00111     assertion = assertion && (gg.west_bndy() == aa);
00112     assertion = assertion && (gg.east_bndy() == bb);
00113     assertion = assertion && (gg.num_cells_x() == nn);
00114     assertion = assertion && (gg.south_bndy() == cc);
00115     assertion = assertion && (gg.north_bndy() == dd);
00116     assertion = assertion && (gg.num_cells_y() == mm);
00117
00118     mtk::Tools::EndUnitTestNo(3);
00119     mtk::Tools::Assert(assertion);
00120 }
00121
00122 mtk::Real ScalarField(mtk::Real xx, mtk::Real yy) {
00123
00124     mtk::Real aux{-(1.0/2.0)*xx*xx - (1.0/2.0)*yy*yy};
00125
00126     return xx*yy*exp(aux);
00127 }
00128
00129 void TestBindScalarFieldWriteToFile() {
00130
00131     mtk::Tools::BeginUnitTestNo(4);
00132
00133     mtk::Real aa = 0.0;
00134     mtk::Real bb = 1.0;
00135     mtk::Real cc = 0.0;
00136     mtk::Real dd = 1.0;
00137
00138     int nn = 5;
00139     int mm = 5;
00140
00141     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm);
00142
00143     gg.BindScalarField(ScalarField);
00144
00145     if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_04.dat", "x", "y", "u(x,y)")) {
00146         std::cerr << "Error writing to file." << std::endl;
00147     }
00148
00149     mtk::Tools::EndUnitTestNo(4);
00150 }
00151
00152 mtk::Real VectorFieldPComponent(mtk::Real xx, mtk::Real yy) {
00153
00154     return xx + 0.01;
00155 }
00156
00157 mtk::Real VectorFieldQComponent(mtk::Real xx, mtk::Real yy) {
00158
00159     return yy + 0.01;
00160 }
00161
00162 void TestBindVectorField() {
00163
00164     mtk::Tools::BeginUnitTestNo(5);
00165
00166     mtk::Real aa = 0.0;
00167     mtk::Real bb = 1.0;
00168     mtk::Real cc = 0.0;
00169     mtk::Real dd = 1.0;
00170
00171     int nn = 5;
00172     int mm = 5;
00173
00174     mtk::UniStgGrid2D gg(aa, bb, nn, cc, dd, mm, mtk::VECTOR);
00175
00176     gg.BindVectorField(VectorFieldPComponent, VectorFieldQComponent);
00177

```

```
00178     std::cout << gg << std::endl;
00179
00180     if(!gg.WriteToFile("mtk_uni_stg_grid_2d_test_05.dat", "x", "y", "v(x,y)")) {
00181         std::cerr << "Error writing to file." << std::endl;
00182     }
00183
00184     mtk::Tools::EndUnitTestNo(5);
00185 }
00186
00187 int main () {
00188
00189     std::cout << "Testing mtk::UniStgGrid2D class." << std::endl;
00190
00191     TestDefaultConstructor();
00192     TestConstructWithWestEastNumCellsXSouthNorthBndysNumCellsYOSTreamOperator();
00193     TestGetters();
00194     TestBindScalarFieldWriteToFile();
00195     TestBindVectorField();
00196 }
00197
00198 #else
00199 #include <iostream>
00200 using std::cout;
00201 using std::endl;
00202 int main () {
00203     cout << "This code HAS to be compiled with support for C++11." << endl;
00204     cout << "Exiting..." << endl;
00205 }
00206 #endif
```

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