MTK: Mimetic Methods Toolkit

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Contents

Chapter 1

Introduction

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

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

1.1 MTK Concerns

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

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

In order of dependence these are:

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

1.2 MTK Flavors

The MTK collection of wrappers is:

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

Others are being designed and developed.

1.3 Contact, Support and Credits

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

Developers are members of:

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

Currently the developers are:

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

1.4 Acknowledgements and Contributions

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

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

Chapter 2

Programming Tools

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

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

Chapter 3

Licensing and Modifications

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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 of source code must retain the above copyright notice, this list of conditions and the following disclaimer.
4. 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 discretization** methods for the numerical solution of ordinary and partial differential equations.

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

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

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

For OS X:

There are no dependences for OS X.

3. Installation

PART 1. CONFIGURATION OF THE MAKEFILE.

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

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

Options are:
- make: builds only the library and the examples.
- all: builds the library, the examples and the documentation.
- mtklib: builds the library, i.e. generates the archive files.
```

```
- test: generates the tests.
- example: generates the examples.
- 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.
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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 processor 1.73GHz 2048 KB of cache and stepping of 8
   gcc version 4.6.3 (Ubuntu/Linaro 4.6.3-1ubuntu5)
```

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::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 condition, const char *fname, int lineno, const char *fxname)

Check if this is the best way of stalling execution.

Member mtk::Tools::test_number_

Check usage of static methods and private members.

File mtk_dense_matrix.h

Add sparse matrices support: BANDED and CRS.

Contemplate manipulation of sparse metrics.

Implement Kronecker product using the BLAS.

File mtk_div_1d.cc

Overload ostream operator as in mtk::Lap1D.

Implement creation of ■ w. mtk::BLASAdapter.

File mtk_glpk_adapter.cc

Document better this file.

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_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 mechanism.

File mtk_uni_stg_grid_1d.h

Create overloaded binding routines that read data from files.

Chapter 9

Bug List

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

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

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

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

Chapter 10

Module Index

10.1 Modules

Here is a list of all modules:

Chapter 11

Namespace Index

11.1 Namespace List

Here is a list of all namespaces with brief descriptions:

Chapter 12

Class Index

12.1 Class List

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

Chapter 13

File Index

13.1 File List

Here is a list of all files with brief descriptions:

Chapter 14

Module Documentation

14.1 Roots.

Fundamental execution parameters and defined types.

Typedefs

- typedef float mtk::Real

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

Variables

- const float mtk::kZero {0.0f}

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

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

  Considered tolerance for comparisons in numerical methods.
- const int mtk::kDefaultOrderAccuracy {2}

  Default order of accuracy for mimetic operators.
- const float mtk::kDefaultMimeticThreshold {1.e-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 {1.e-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.

14.2.1 Detailed Description

Enumerations.

14.2.2 Enumeration Type Documentation

14.2.2.1 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.

14.2.2.2 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.

14.2.2.3 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.

14.6.1 Detailed Description

Uniform rectangular staggered grids.

14.7 Mimetic operators.

Mimetic operators.

Classes

- class mtk::Div1D

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

  Implements a 1D mimetic gradient operator.
- class mtk::Lap1D

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

  Implements a 1D mimetic quadrature.

14.7.1 Detailed Description

Mimetic operators.

Chapter 15

Namespace Documentation

15.1 mtk Namespace Reference

Mimetic Methods Toolkit namespace.

Classes

- class 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 GLPKAdapter

  Adapter class for the GLPK API.
- class Grad1D

  Implements a 1D mimetic gradient operator.
- class Lap1D

  Implements a 1D mimetic Laplacian operator.
- class LAPACKAdapter

  Adapter class for the LAPACK API.
- class Matrix

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

  Implements a 1D mimetic quadrature.
- class Tools

  Tool manager class.
- class UniStgGrid1D

  Uniform 1D Staggered Grid.

Typedefs

- typedef float Real

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

Enumerations

- enum MatrixStorage { DENSE, BANDED, CRS }

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

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

  Nature of the field discretized in a given grid.

Functions

- float snrm2_ (int *n, Real *x, int *incx)
- void sgemv_ (char *trans, int *m, int *n, Real *alpha, Real *a, int *lda, Real *x, int *incx, Real *beta, Real *y, int *incy)
- void sgemm_ (char *transa, char *transb, int *m, int *n, int *k, Real *alpha, Real *a, int *lda, Real *b, aamm int *ldb, Real *beta, Real *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::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)

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 {1.e-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::UniStgGrid1D & *in*)

1. Print spatial coordinates.

Definition at line 68 of file mtk_uni_stg_grid_1d.cc.

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

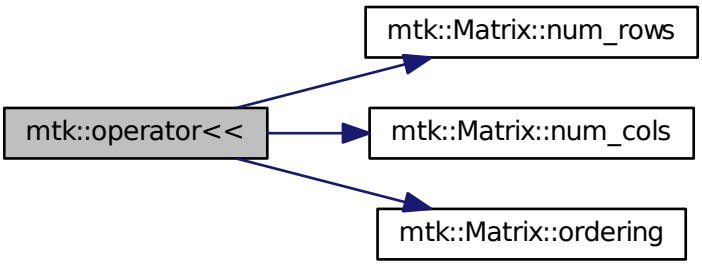
1. Print order of accuracy.
2. Print approximating coefficients for the interior.
3. No weights, thus print the mimetic boundary coefficients.

Definition at line 73 of file mtk_lap_1d.cc.

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

Definition at line 75 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



15.1.1.4 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.

15.1.1.5 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.

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

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

The following options are provided:

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

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

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

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

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

See Also

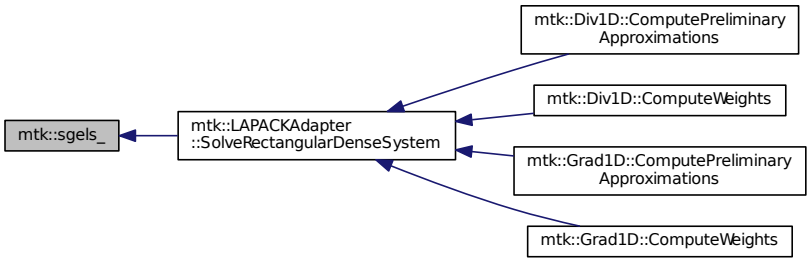
http://www.math.utah.edu/software/lapack/lapack-s/sgels.html

Parameters

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

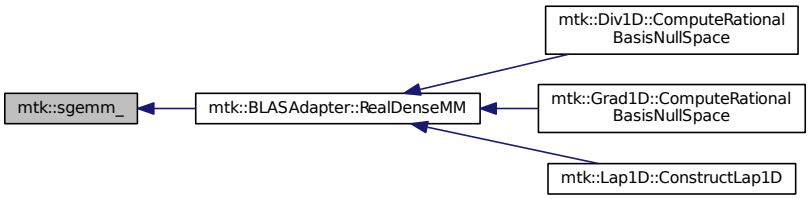
in,out	*work*	On exit, if info = 0, work(1) is optimal lwork.
in,out	*lwork*	The dimension of the array work.
in,out	*info*	If info = 0, then successful exit.

Here is the caller graph for this function:



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

Here is the caller graph for this function:



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

Here is the caller graph for this function:

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

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

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

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

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

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

See Also

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

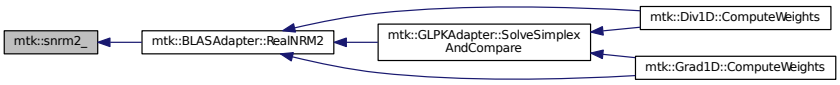
Parameters

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

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

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

Here is the caller graph for this function:



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

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

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

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

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

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

See Also

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

Parameters

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

Chapter 16

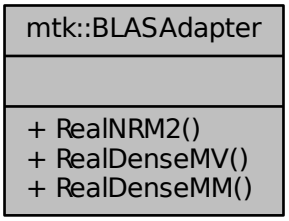
Class Documentation

16.1 mtk::BLASAdapter Class Reference

Adapter class for the BLAS API.

`#include <mtk_blas_adapter.h>`

Collaboration diagram for mtk::BLASAdapter:



Static Public Member Functions

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

  Compute the $|\mathbf{x}|_2$ of given array $\mathbf{x}$.
- static void 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.

16.1.1 Detailed Description

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

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

See Also

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

Definition at line 96 of file mtk_blas_adapter.h.

16.1.2 Member Function Documentation

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

Performs:

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

Parameters

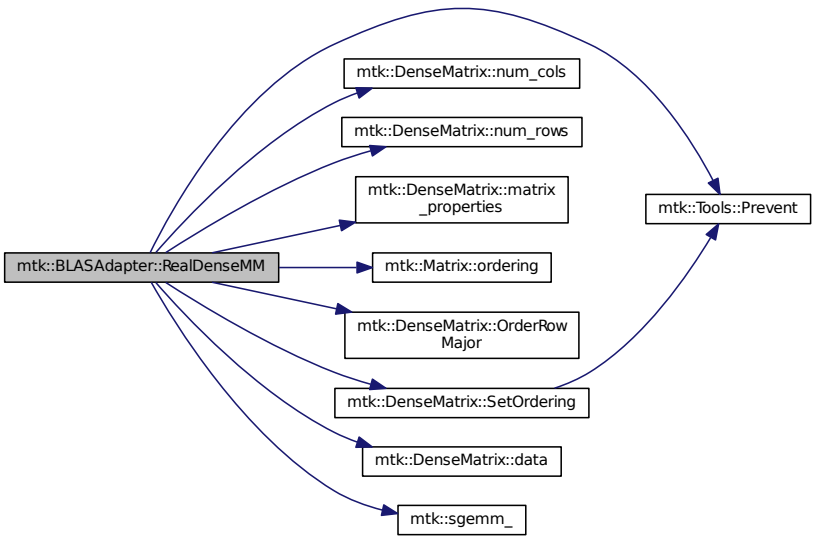
in	*aa*	First matrix.
in	*bb*	Second matrix.

See Also

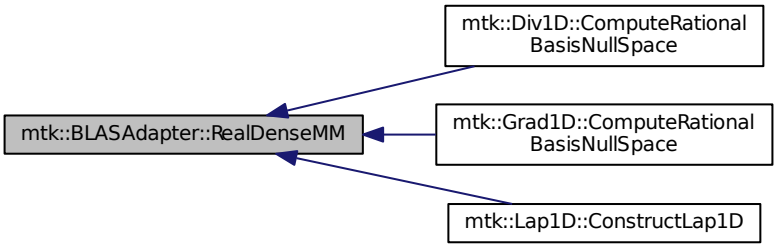
http://ejspeiro.github.io/Netlib-and-CPP/

Definition at line 318 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Performs

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

Parameters

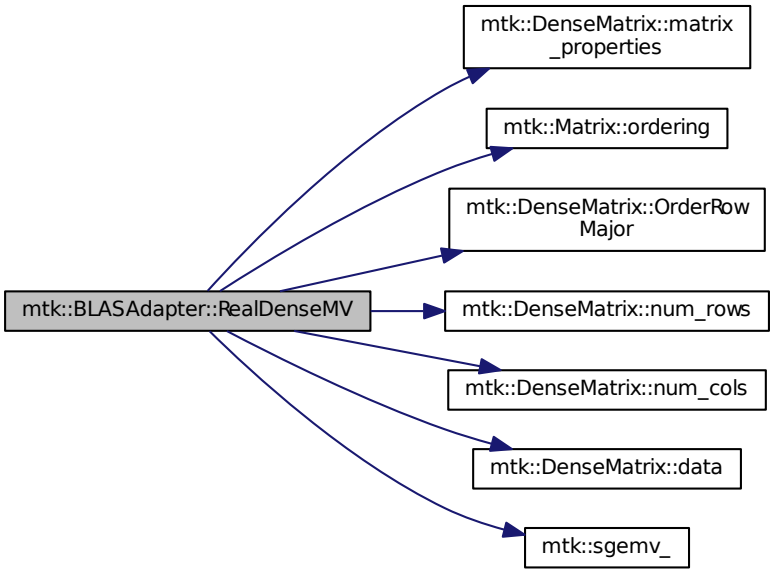
in	*alpha*	First scalar.
in	*aa*	Given matrix.
in	*xx*	First vector.
in	*beta*	Second scalar.
in,out	*yy*	Second vector (output).

See Also

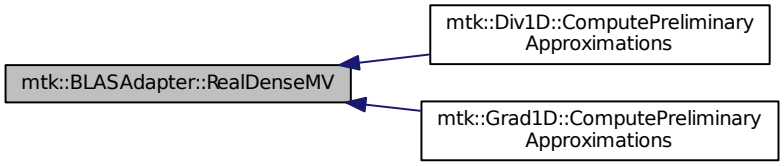
http://ejspeiro.github.io/Netlib-and-CPP/

Definition at line 287 of file mtk_blas_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

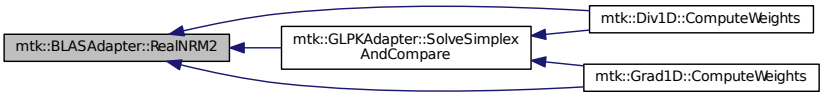
Parameters

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

Definition at line 276 of file mtk_blas_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:

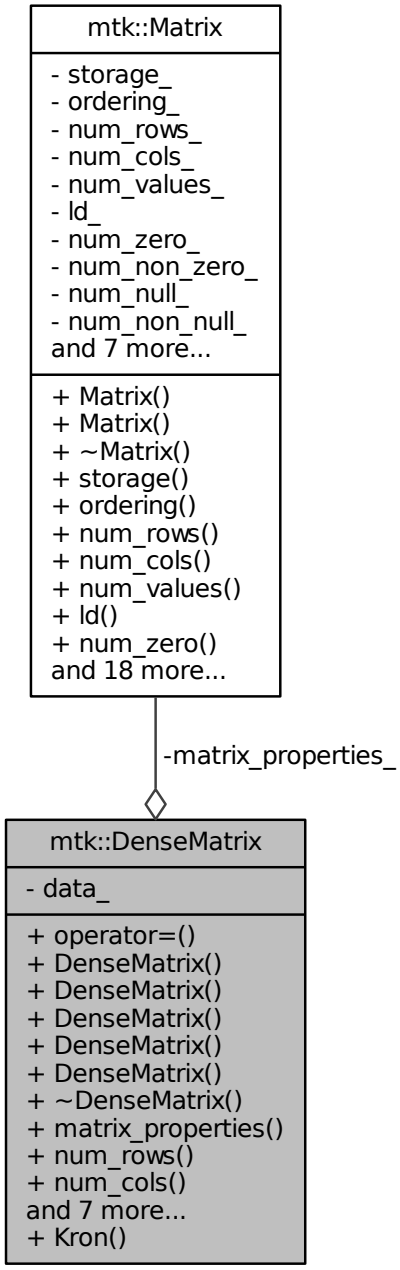
- include/mtk_blas_adapter.h
- src/mtk_blas_adapter.cc

16.2 mtk::DenseMatrix Class Reference

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

`#include <mtk_dense_matrix.h>`

Collaboration diagram for mtk::DenseMatrix:



Public Member Functions

- DenseMatrix & operator= (const DenseMatrix &in)

Overloaded assignment operator.

- 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.

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 contiguouos position in memory.

Friends

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

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

16.2.1 Detailed Description

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

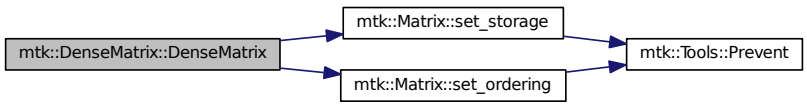
Definition at line 98 of file mtk_dense_matrix.h.

16.2.2 Constructor & Destructor Documentation

16.2.2.1 mtk::DenseMatrix::DenseMatrix ( )

Definition at line 138 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



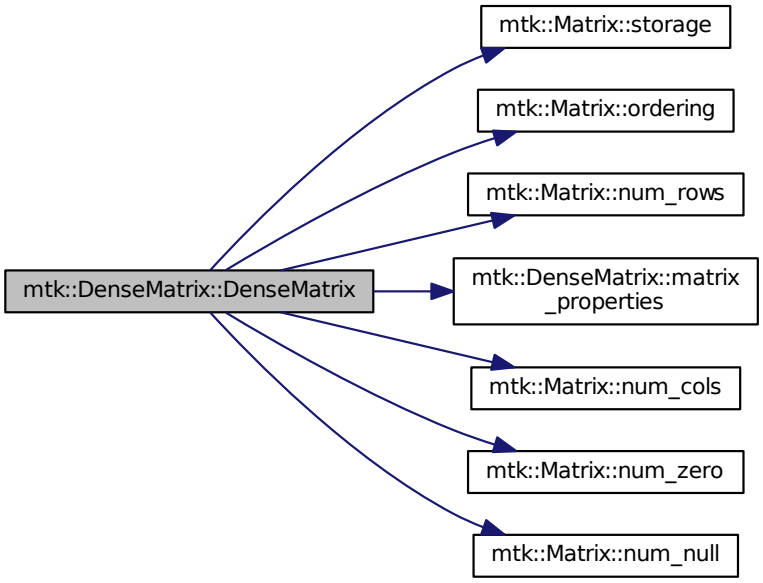
16.2.2.2 mtk::DenseMatrix::DenseMatrix (const DenseMatrix & *in*)

Parameters

in	*in*	Given matrix.

Definition at line 144 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 177 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

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

Used in the construction of the mimetic operators.

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

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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 199 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

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

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

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

This constructor generates a Vandermonde matrix, as defined above.

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

Parameters

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

Exceptions

std::bad_alloc	

Definition at line 237 of file mtk_dense_matrix.cc.

Here is the call graph for this function:

16.2.2.6 mtk::DenseMatrix::~DenseMatrix ( )

Definition at line 285 of file mtk_dense_matrix.cc.

16.2.3 Member Function Documentation

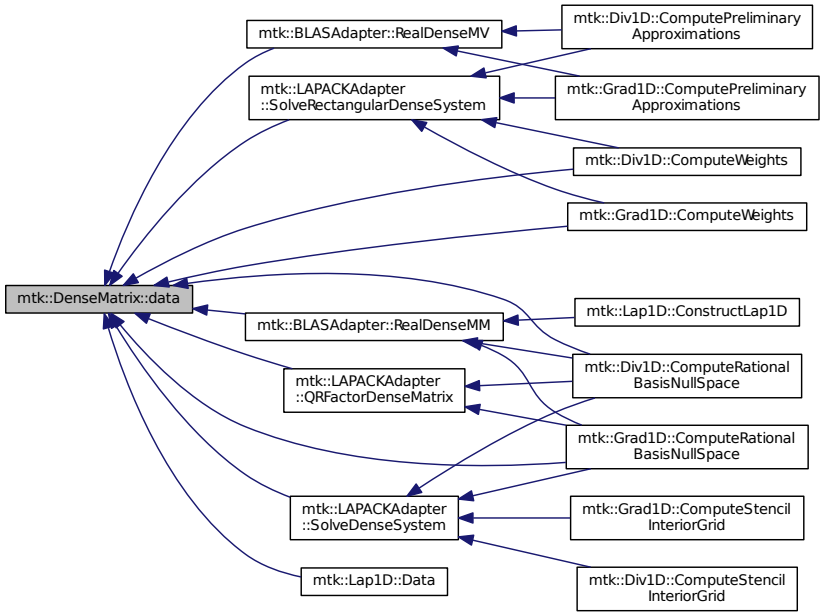
16.2.3.1 mtk::Real * mtk::DenseMatrix::data ( ) const

Returns

Pointer to an array of mtk::Real.

Definition at line 316 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



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

Parameters

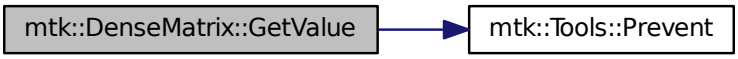
in	*row_coord*	Row coordinate.
in	*col_coord*	Column coordinate.

Returns

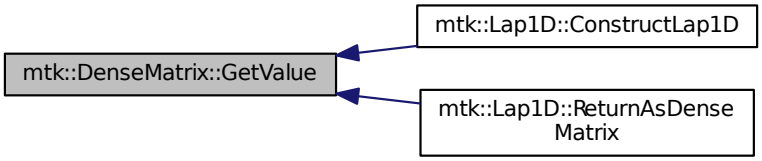
The required value at the specified coordinates.

Definition at line 321 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Parameters

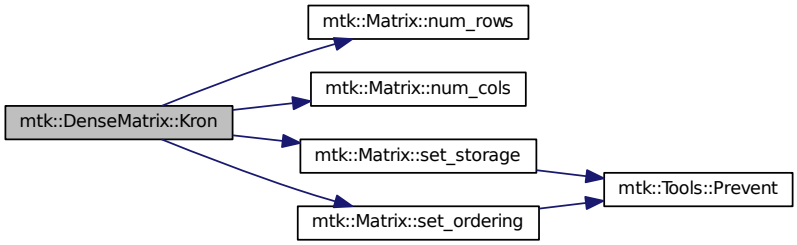
in	*aa*	First matrix.
in	*bb*	Second matrix.

Exceptions

std::bad_alloc	

Definition at line 463 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



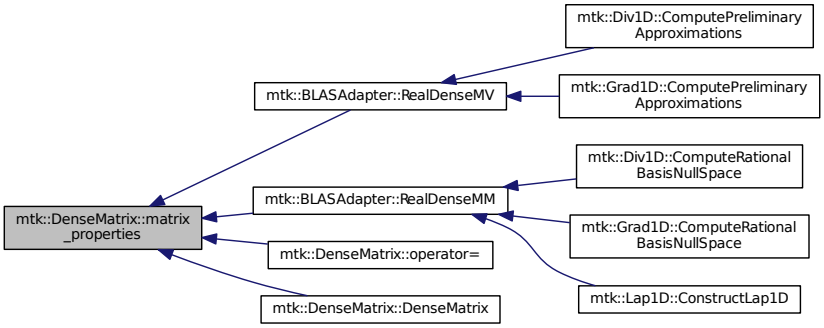
16.2.3.4 mtk::Matrix mtk::DenseMatrix::matrix_properties ( ) const

Returns

Pointer to a Matrix.

Definition at line 291 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



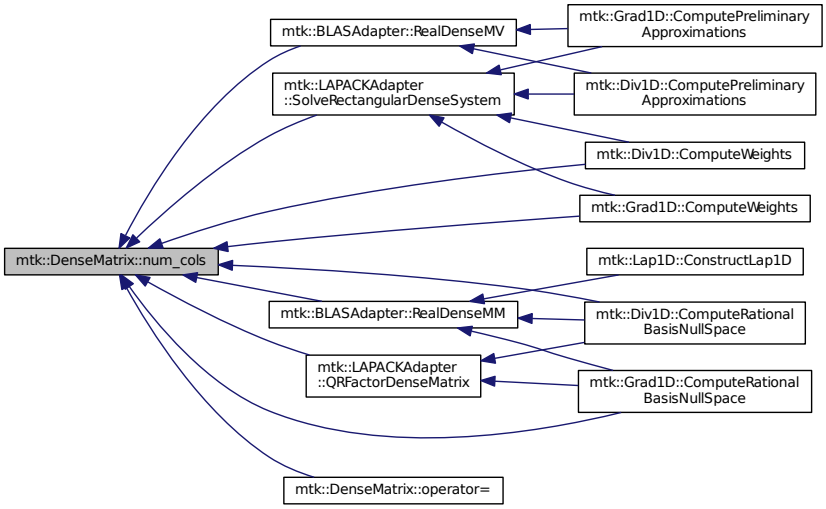
16.2.3.5 int mtk::DenseMatrix::num_cols ( ) const

Returns

Number of columns of the matrix.

Definition at line 311 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



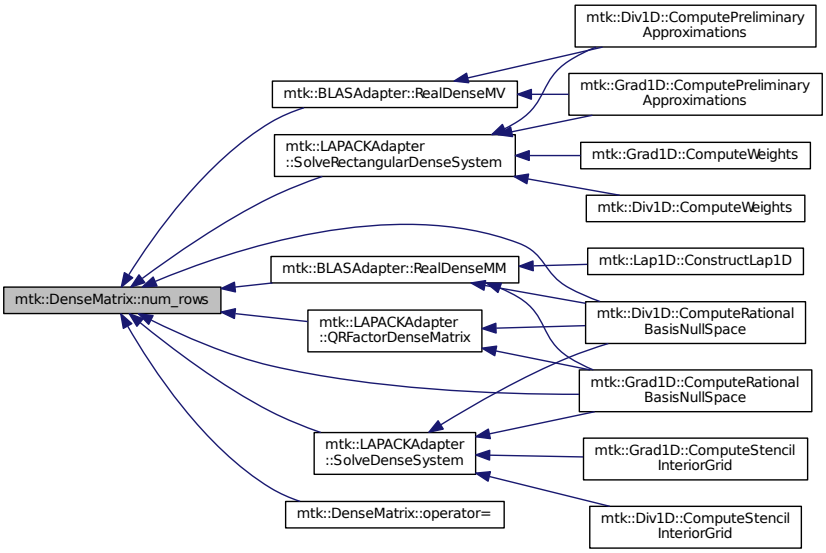
16.2.3.6 int mtk::DenseMatrix::num_rows ( ) const

Returns

Number of rows of the matrix.

Definition at line 306 of file mtk_dense_matrix.cc.

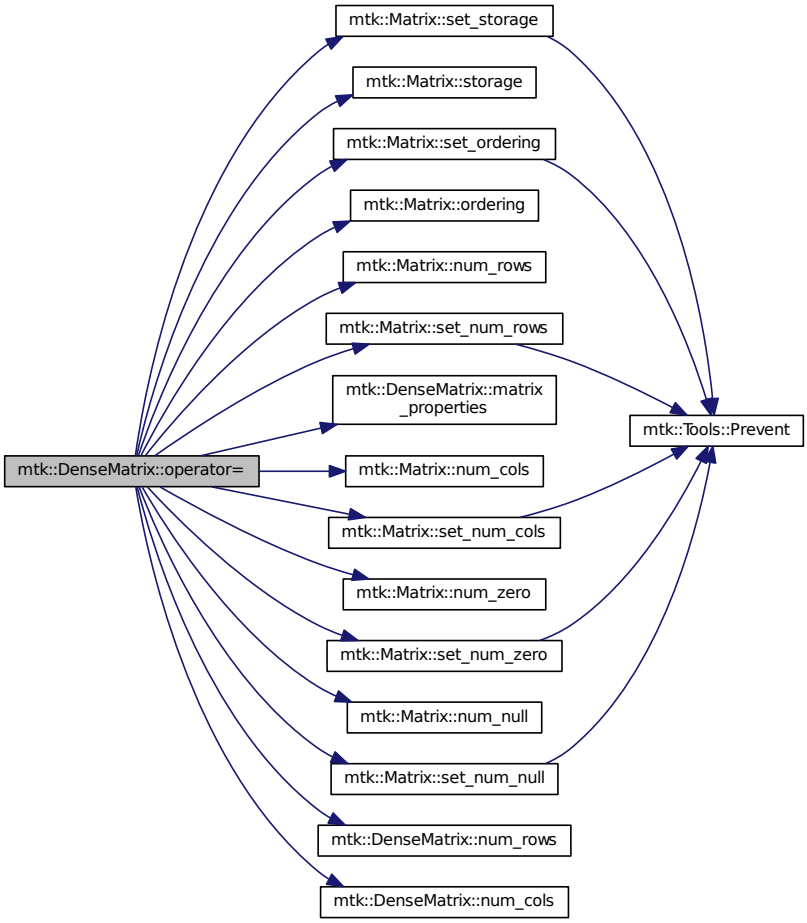
Here is the caller graph for this function:



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

Definition at line 97 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



16.2.3.8 void mtk::DenseMatrix::OrderColMajor ( )

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

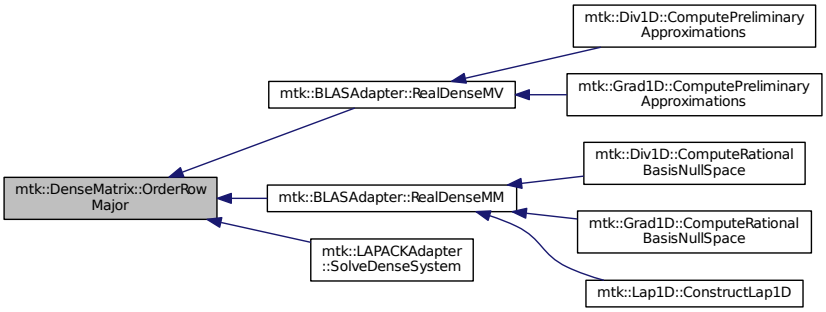
Definition at line 424 of file mtk_dense_matrix.cc.

16.2.3.9 void mtk::DenseMatrix::OrderRowMajor ( )

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

Definition at line 383 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



16.2.3.10 void mtk::DenseMatrix::SetOrdering (mtk::MatrixOrdering *oo*)

Parameters

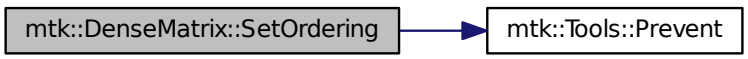
in	*oo*	Ordering.

Returns

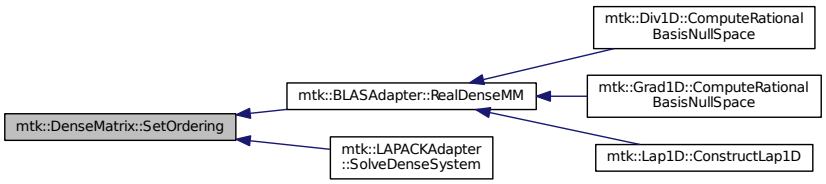
The required value at the specified coordinates.

Definition at line 296 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



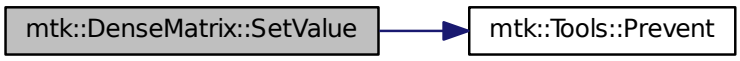
16.2.3.11 void mtk::DenseMatrix::SetValue (const int & *row_coord,* const int & *col_coord,* const Real & *val*)

Parameters

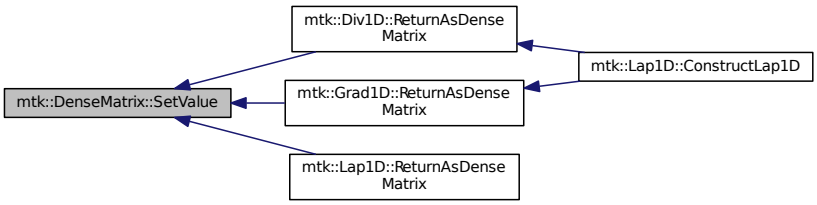
in	*row_coord*	Row coordinate.
in	*col_coord*	Column coordinate.
in	*val*	Row Actual value to be inserted.

Definition at line 333 of file mtk_dense_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

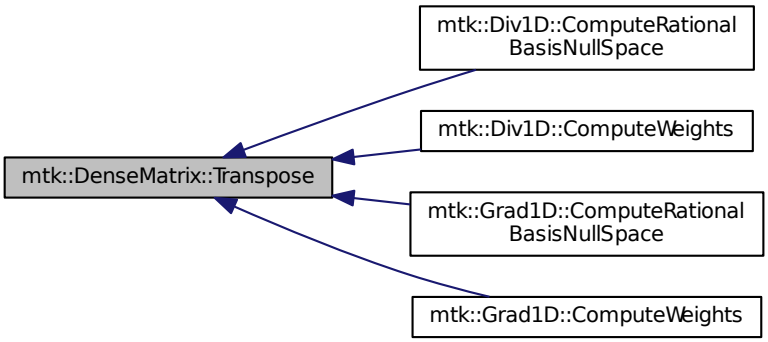


16.2.3.12 void mtk::DenseMatrix::Transpose ( )

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

Definition at line 346 of file mtk_dense_matrix.cc.

Here is the caller graph for this function:



16.2.4 Friends And Related Function Documentation

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

Definition at line 75 of file mtk_dense_matrix.cc.

16.2.5 Member Data Documentation

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

Definition at line 274 of file mtk_dense_matrix.h.

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

Definition at line 272 of file mtk_dense_matrix.h.

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

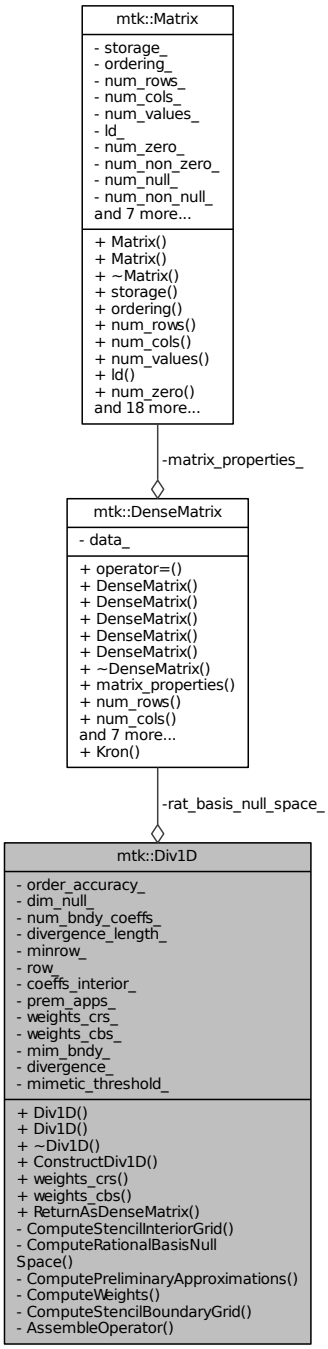
- include/mtk_dense_matrix.h
- src/mtk_dense_matrix.cc

16.3 mtk::Div1D Class Reference

Implements a 1D mimetic divergence operator.

`#include <mtk_div_1d.h>`

Collaboration diagram for mtk::Div1D:



Public Member Functions

- Div1D ()

Default constructor.

- Div1D (const Div1D &div)

  Copy constructor.

- ~Div1D ()

  Destructor.

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

  Factory method implementing the CBS Algorithm to build operator.

- Real * weights_crs (void)

  Return collection of weights as computed by the CRSA.

- Real * weights_cbs (void)

  Return collection of weights as computed by the CBSA.

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid)

  Return the operator as a dense matrix.

Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  Stage 1 of the CBS Algorithm.

- bool ComputeRationalBasisNullSpace (void)

  Stage 2.1 of the CBS Algorithm.

- bool ComputePreliminaryApproximations (void)

  Stage 2.2 of the CBS Algorithm.

- bool ComputeWeights (void)

  Stage 2.3 of the CBS Algorithm.

- bool ComputeStencilBoundaryGrid (void)

  Stage 2.4 of the CBS Algorithm.

- bool AssembleOperator (void)

  Stage 3 of the CBS Algorithm.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.

- int dim_null_

  Dim. null-space for boundary approximations.

- int num_bndy_coeffs_

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

- int divergence_length_

  Length of the output array.

- int minrow_

  Row from the optimizer with the minimum rel. nor.

- int row_

  Row currently processed by the optimizer.

- mtk::DenseMatrix rat_basis_null_space_

  Rational b. null-space w. bndy.

- Real * coeffs_interior_

Interior stencil.

- Real * prem_apps_

  2D array of boundary preliminary approximations.

- Real * weights_crs_

  Array containing weights from CRSA.

- Real * weights_cbs_

  Array containing weights from CBSA.

- Real * mim_bndy_

  Array containing mimetic boundary approximations.

- Real * divergence_

  Output array containing the operator and weights.

- Real mimetic_threshold_

  < Mimetic threshold.

Friends

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

  Output stream operator for printing.

16.3.1 Detailed Description

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

Definition at line 81 of file mtk_div_1d.h.

16.3.2 Constructor & Destructor Documentation

16.3.2.1 mtk::Div1D::Div1D ( )

Definition at line 125 of file mtk_div_1d.cc.

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

Parameters

in	*div*	Given divergence.

Definition at line 140 of file mtk_div_1d.cc.

16.3.2.3 mtk::Div1D::~Div1D ( )

Definition at line 155 of file mtk_div_1d.cc.

16.3.3 Member Function Documentation

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

Construct the output array with the operator and its weights.

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

Definition at line 1306 of file mtk_div_1d.cc.

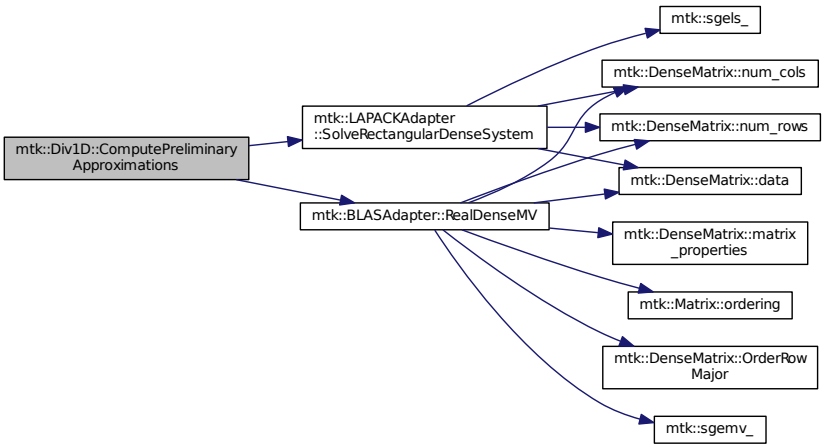
16.3.3.2 bool mtk::Div1D::ComputePreliminaryApproximations (void) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

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

Definition at line 662 of file mtk_div_1d.cc.

Here is the call graph for this function:



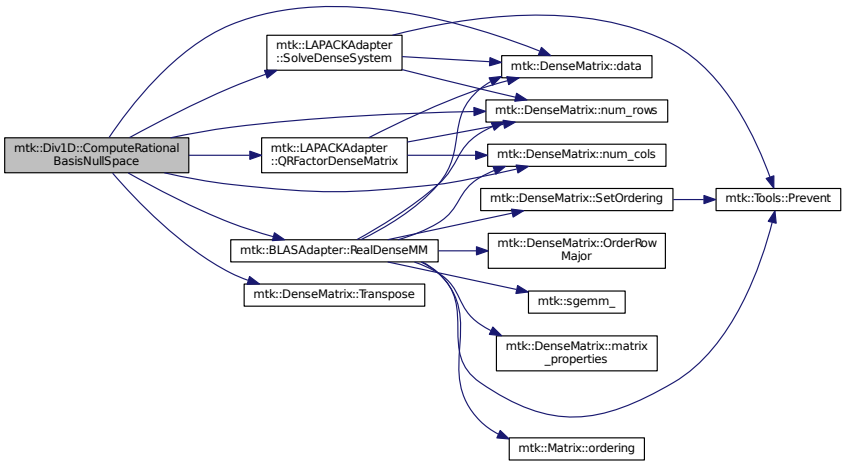
16.3.3.3 bool mtk::Div1D::ComputeRationalBasisNullSpace (void) [private]

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 486 of file mtk_div_1d.cc.

Here is the call graph for this function:



16.3.3.4 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 1207 of file mtk_div_1d.cc.

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

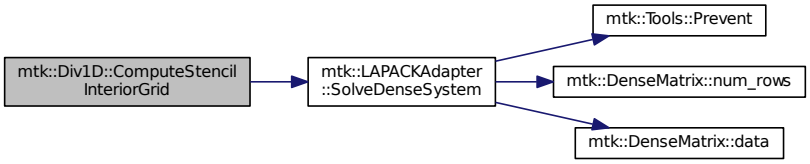
Compute the stencil approximating the interior of the staggered grid.

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 387 of file mtk_div_1d.cc.

Here is the call graph for this function:



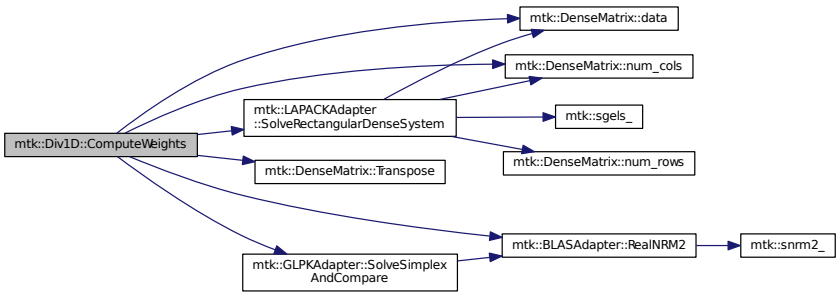
16.3.3.6 bool mtk::Div1D::ComputeWeights (void) [private]

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

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

Definition at line 882 of file mtk_div_1d.cc.

Here is the call graph for this function:



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

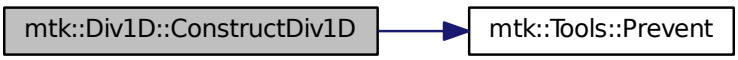
Returns

Success of the construction.

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

Definition at line 176 of file mtk_div_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

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

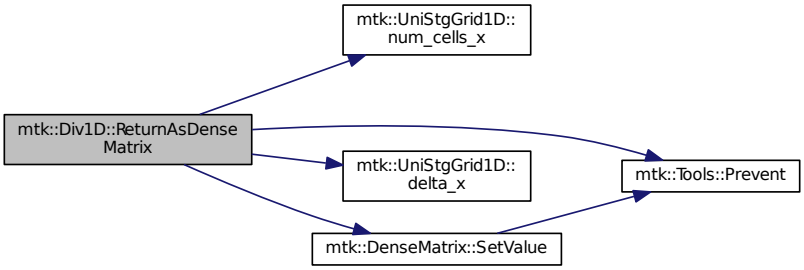
Returns

The operator as a dense matrix.

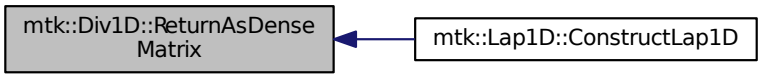
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 325 of file mtk_div_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



16.3.3.9 mtk::Real * mtk::Div1D::weights_cbs (void)

Returns

Collection of weights as computed by the CBSA.

Definition at line 320 of file mtk_div_1d.cc.

16.3.3.10 mtk::Real * mtk::Div1D::weights_crs (void)

Returns

Collection of weights as computed by the CRSA.

Definition at line 315 of file mtk_div_1d.cc.

16.3.4 Friends And Related Function Documentation

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

1. Print order of accuracy.

2. Print approximating coefficients for the interior.
3. Print mimetic weights.
4. Print mimetic approximations at the boundary.

Definition at line 79 of file mtk_div_1d.cc.

16.3.5 Member Data Documentation

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

Definition at line 182 of file mtk_div_1d.h.

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

Definition at line 173 of file mtk_div_1d.h.

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

Definition at line 187 of file mtk_div_1d.h.

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

Definition at line 175 of file mtk_div_1d.h.

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

Definition at line 186 of file mtk_div_1d.h.

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

Definition at line 189 of file mtk_div_1d.h.

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

Definition at line 177 of file mtk_div_1d.h.

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

Definition at line 174 of file mtk_div_1d.h.

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

Definition at line 172 of file mtk_div_1d.h.

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

Definition at line 183 of file mtk_div_1d.h.

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

Definition at line 180 of file mtk_div_1d.h.

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

Definition at line 178 of file mtk_div_1d.h.

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

Definition at line 185 of file mtk_div_1d.h.

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

Definition at line 184 of file mtk_div_1d.h.

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

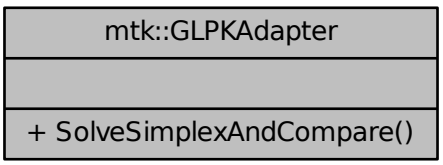
- include/mtk_div_1d.h
- src/mtk_div_1d.cc

16.4 mtk::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.

16.4.1 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 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.

16.4.2 Member Function Documentation

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

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

Parameters

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

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.

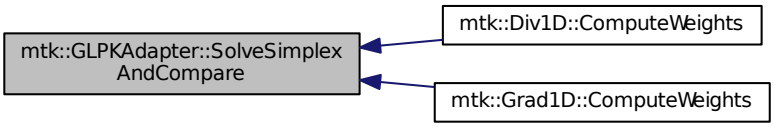
7. Copy the matrix minus the row objective to the glpk problem.

8. Solve problem.

Definition at line 78 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:

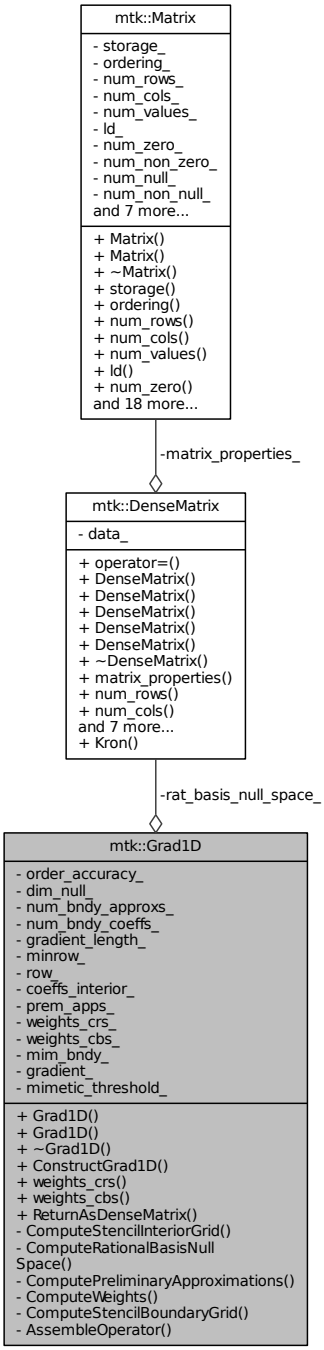
- include/mtk_glpk_adapter.h
- src/mtk_glpk_adapter.cc

16.5 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.

- Real * weights_crs (void)

  Return collection of weights as computed by the CRSA.

- Real * weights_cbs (void)

  Return collection of weights as computed by the CBSA.

- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid)

  Return the operator as a dense matrix.

Private Member Functions

- bool ComputeStencilInteriorGrid (void)

  Stage 1 of the CBS Algorithm.

- bool ComputeRationalBasisNullSpace (void)

  Stage 2.1 of the CBS Algorithm.

- bool ComputePreliminaryApproximations (void)

  Stage 2.2 of the CBS Algorithm.

- bool ComputeWeights (void)

  Stage 2.3 of the CBS Algorithm.

- bool ComputeStencilBoundaryGrid (void)

  Stage 2.4 of the CBS Algorithm.

- bool AssembleOperator (void)

  Stage 3 of the CBS Algorithm.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.

- int dim_null_

  Dim. null-space for boundary approximations.

- int num_bndy_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.

- mtk::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.

16.5.1 Detailed Description

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

Definition at line 81 of file mtk_grad_1d.h.

16.5.2 Constructor & Destructor Documentation

16.5.2.1 mtk::Grad1D::Grad1D ( )

Definition at line 129 of file mtk_grad_1d.cc.

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

Parameters

in	*div*	Given divergence.

Definition at line 145 of file mtk_grad_1d.cc.

16.5.2.3 mtk::Grad1D::~Grad1D ( )

Definition at line 161 of file mtk_grad_1d.cc.

16.5.3 Member Function Documentation

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

Construct the output array with the operator and its weights.

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

Definition at line 1344 of file mtk_grad_1d.cc.

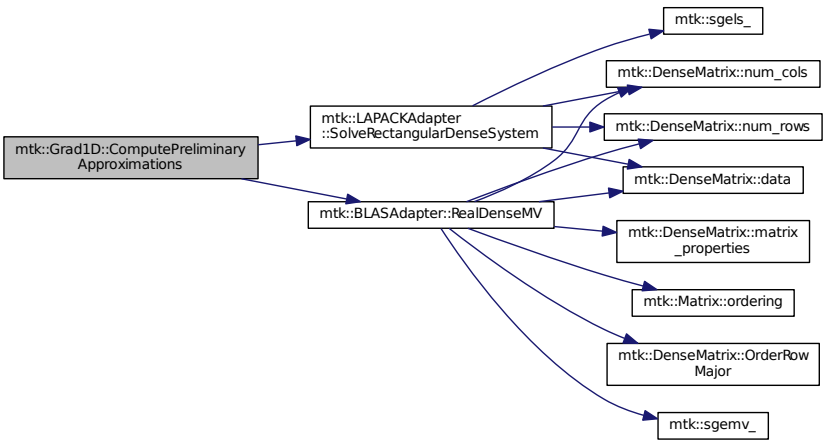
16.5.3.2 bool mtk::Grad1D::ComputePreliminaryApproximations (void) [private]

Compute the set of preliminary approximations on the boundary neighborhood.

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

Definition at line 680 of file mtk_grad_1d.cc.

Here is the call graph for this function:



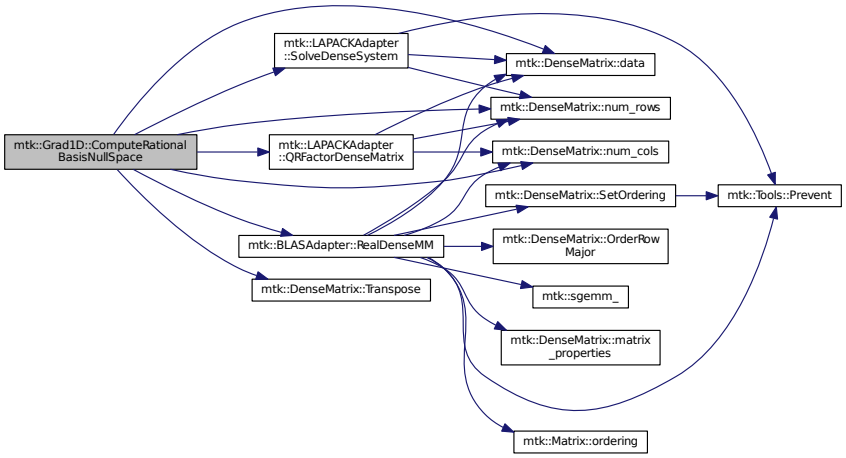
16.5.3.3 bool mtk::Grad1D::ComputeRationalBasisNullSpace (void) [private]

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 497 of file mtk_grad_1d.cc.

Here is the call graph for this function:



16.5.3.4 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 1238 of file mtk_grad_1d.cc.

16.5.3.5 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 401 of file mtk_grad_1d.cc.

Here is the call graph for this function:

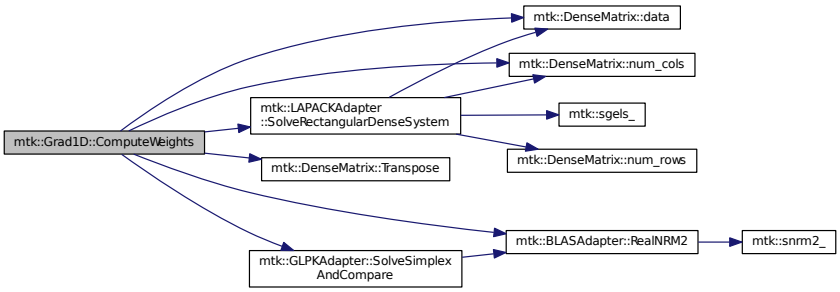
16.5.3.6 bool mtk::Grad1D::ComputeWeights (void) [private]

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

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

Definition at line 900 of file mtk_grad_1d.cc.

Here is the call graph for this function:



16.5.3.7 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:

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

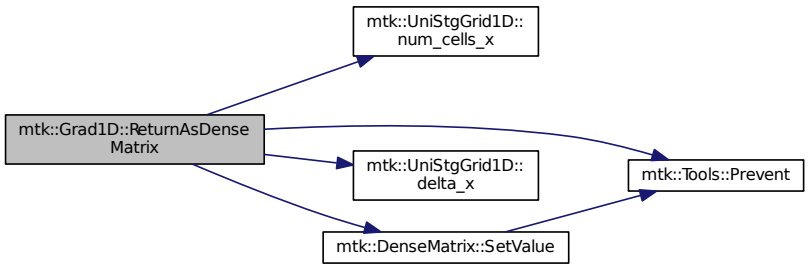
Returns

The operator as a dense matrix.

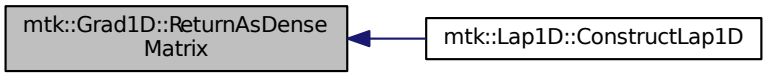
1. Insert mimetic boundary at the west.
2. Insert coefficients for the interior of the grid.
3. Impose center-skew symmetry by permuting the mimetic boundaries.

Definition at line 335 of file mtk_grad_1d.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



16.5.3.9 mtk::Real * mtk::Grad1D::weights_cbs (void)

Returns

Collection of weights as computed by the CBSA.

Definition at line 330 of file mtk_grad_1d.cc.

16.5.3.10 mtk::Real * mtk::Grad1D::weights_crs (void)

Returns

Success of the solution.

Definition at line 325 of file mtk_grad_1d.cc.

16.5.4 Friends And Related Function Documentation

16.5.4.1 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.

16.5.5 Member Data Documentation

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

Definition at line 183 of file mtk_grad_1d.h.

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

Definition at line 173 of file mtk_grad_1d.h.

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

Definition at line 188 of file mtk_grad_1d.h.

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

Definition at line 176 of file mtk_grad_1d.h.

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

Definition at line 187 of file mtk_grad_1d.h.

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

Definition at line 190 of file mtk_grad_1d.h.

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

Definition at line 178 of file mtk_grad_1d.h.

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

Definition at line 174 of file mtk_grad_1d.h.

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

Definition at line 175 of file mtk_grad_1d.h.

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

Definition at line 172 of file mtk_grad_1d.h.

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

Definition at line 184 of file mtk_grad_1d.h.

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

Definition at line 181 of file mtk_grad_1d.h.

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

Definition at line 179 of file mtk_grad_1d.h.

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

Definition at line 186 of file mtk_grad_1d.h.

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

Definition at line 185 of file mtk_grad_1d.h.

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

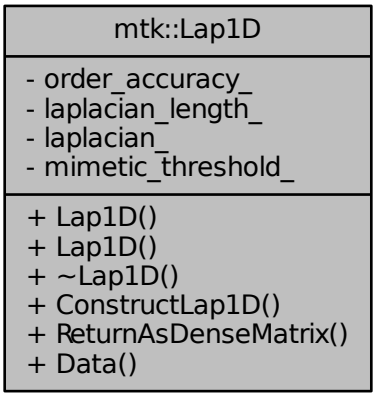
- include/mtk_grad_1d.h
- src/mtk_grad_1d.cc

16.6 mtk::Lap1D Class Reference

Implements a 1D mimetic Laplacian operator.

`#include <mtk_lap_1d.h>`

Collaboration diagram for mtk::Lap1D:



Public Member Functions

- Lap1D ()

  Default constructor.
- Lap1D (const Lap1D &lap)

  Copy constructor.
- ~Lap1D ()

  Destructor.
- bool ConstructLap1D (int order_accuracy=kDefaultOrderAccuracy, Real mimetic_threshold=kDefaultMimeticThreshold)

  Factory method implementing the CBS Algorithm to build operator.
- DenseMatrix ReturnAsDenseMatrix (const UniStgGrid1D &grid)

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

  Return the operator as a dense array.

Private Attributes

- int order_accuracy_

  Order of numerical accuracy of the operator.
- int laplacian_length_

  Length of the output array.
- Real * laplacian_

  Output array containing the operator and weights.
- Real mimetic_threshold_

  < Mimetic threshold.

Friends

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

  Output stream operator for printing.

16.6.1 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.

16.6.2 Constructor & Destructor Documentation

16.6.2.1 mtk::Lap1D::Lap1D ( )

Definition at line 108 of file mtk_lap_1d.cc.

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

Parameters

in	*lap*	Given Laplacian.

16.6.2.3 mtk::Lap1D::~Lap1D ( )

Definition at line 113 of file mtk_lap_1d.cc.

16.6.3 Member Function Documentation

16.6.3.1 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.

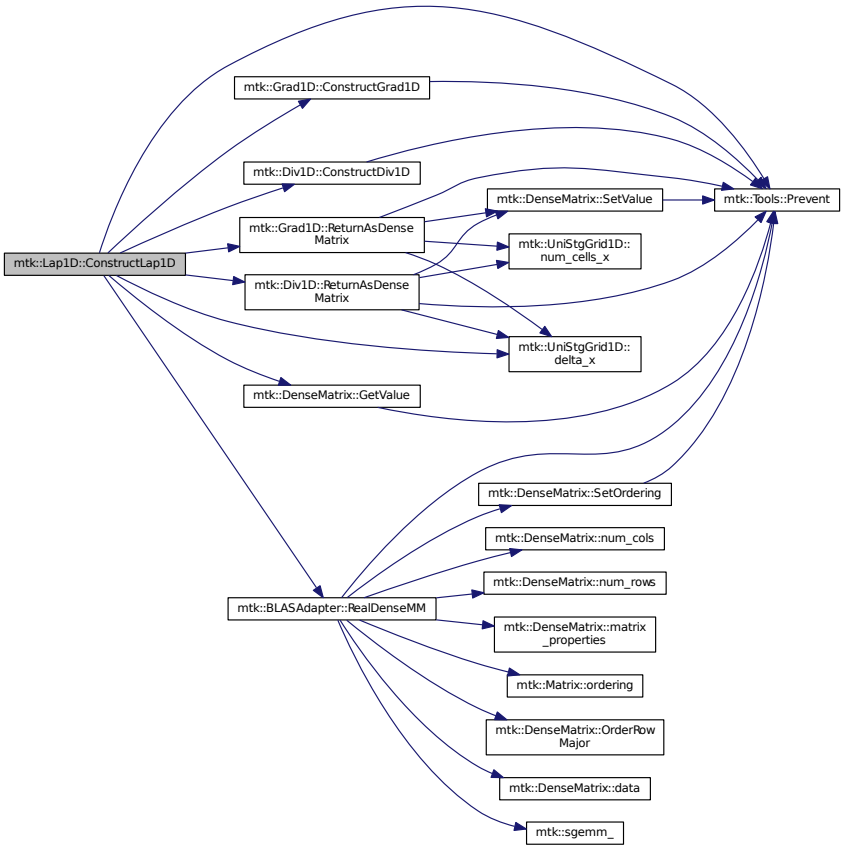
Warning

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:



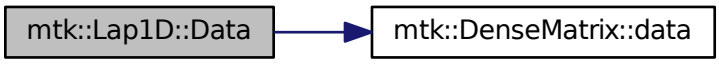
16.6.3.2 mtk::Real * mtk::Lap1D::Data (const UniStgGrid1D & *grid*)

Returns

The operator as a dense array.

Definition at line 332 of file mtk_lap_1d.cc.

Here is the call graph for this function:



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

Returns

The operator as a dense matrix.

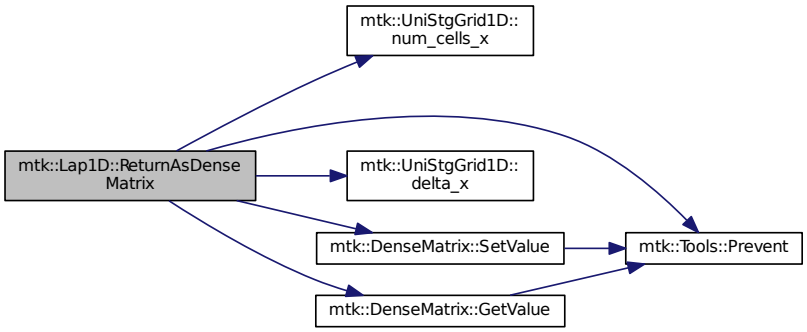
1. Extract mimetic coefficients from the west boundary.
2. Extract interior coefficients.
3. Extract mimetic coefficients from the west boundary to go east.

Note

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

Definition at line 265 of file mtk_lap_1d.cc.

Here is the call graph for this function:



16.6.4 Friends And Related Function Documentation

16.6.4.1 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.

16.6.5 Member Data Documentation

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

Definition at line 120 of file mtk_lap_1d.h.

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

Definition at line 118 of file mtk_lap_1d.h.

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

Definition at line 122 of file mtk_lap_1d.h.

16.6.5.4 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:

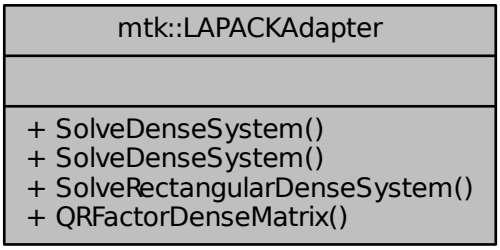
- include/mtk_lap_1d.h
- src/mtk_lap_1d.cc

16.7 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 SolveRectangularDenseSystem (const mtk::DenseMatrix &aa, mtk::Real *ob_, int ob_ld_)

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

  Performs a QR factorization on a dense matrix.

16.7.1 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 the numerical methods implemented in the LAPACK.

The **LAPACK** 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 89 of file mtk_lapack_adapter.h.

16.7.2 Member Function Documentation

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

Adapts the MTK to LAPACK's routine.

Parameters

in,out	*matrix*	Input matrix.

Returns

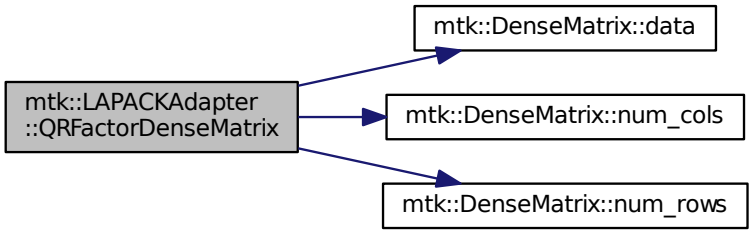
Matrix $\mathbf{Q}$.

Exceptions

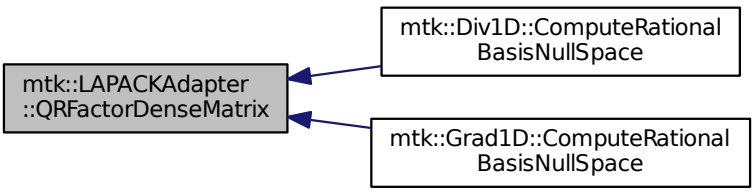
std::bad_alloc	

Definition at line 515 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

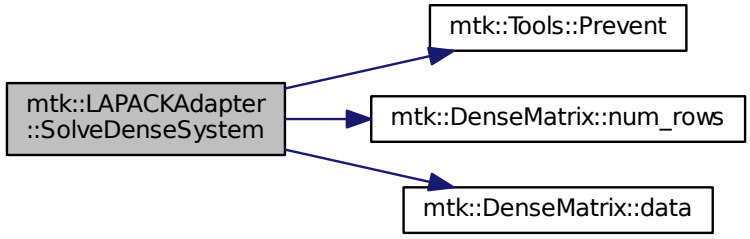
in	*matrix*	Input matrix.
in	*rhs*	Input right-hand sides vector.

Exceptions

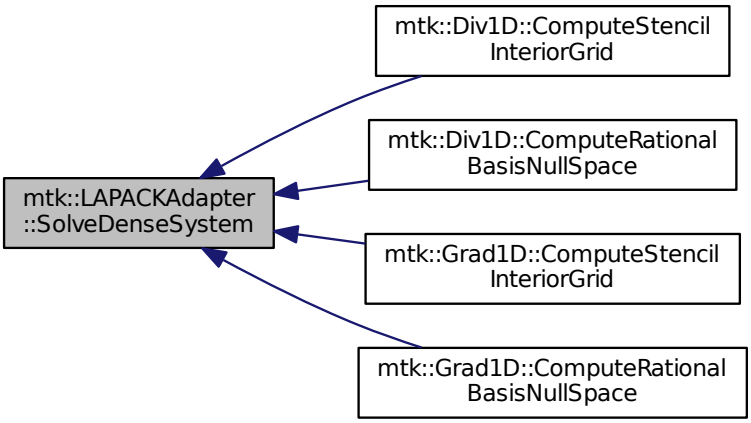
std::bad_alloc	

Definition at line 427 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

Adapts the MTK to LAPACK's dgesv_ routine.

Parameters

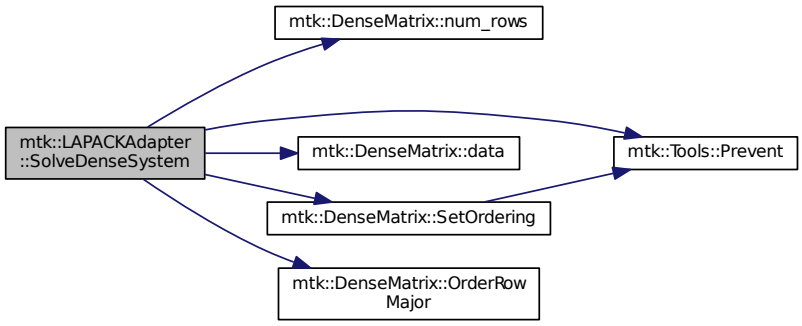
in	*matrix*	Input matrix.
in	*rr*	Input right-hand sides matrix.

Exceptions

std::bad_alloc	

Definition at line 463 of file mtk_lapack_adapter.cc.

Here is the call graph for this function:



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

Adapts the MTK to LAPACK's routine.

Parameters

in,out	*matrix*	Input matrix.

Returns

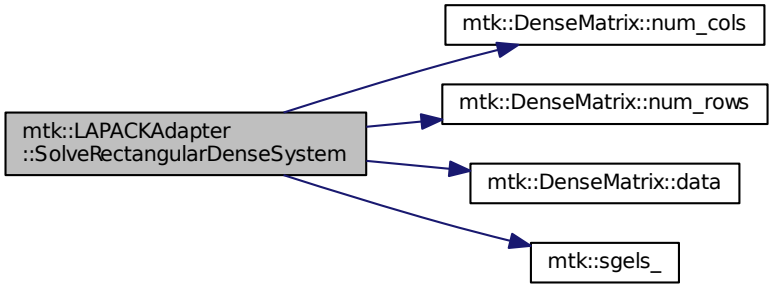
Success of the solution.

Exceptions

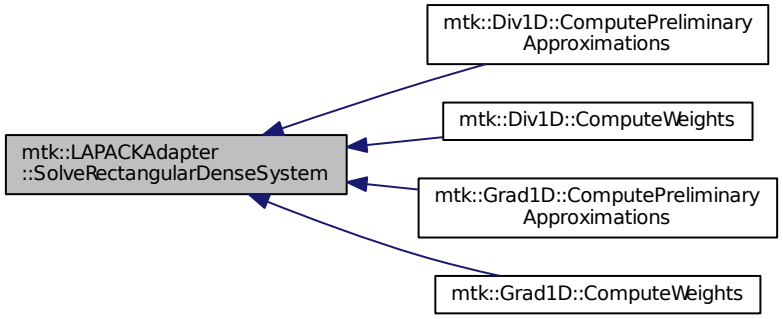
std::bad_alloc	

Definition at line 716 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:

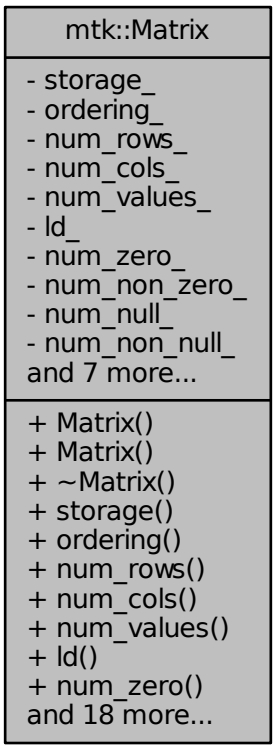
- include/mtk_lapack_adapter.h
- src/mtk_lapack_adapter.cc

16.8 mtk::Matrix Class Reference

Definition of the representation of a matrix in the MTK.

`#include <mtk_matrix.h>`

Collaboration diagram for mtk::Matrix:



Public Member Functions

- Matrix ()

  Default constructor.
- Matrix (const Matrix &in)

  Copy constructor.
- ~Matrix ()

  Destructor.
- MatrixStorage storage () const

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

  Gets the 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.

16.8.1 Detailed Description

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

Definition at line 75 of file mtk_matrix.h.

16.8.2 Constructor & Destructor Documentation

16.8.2.1 mtk::Matrix::Matrix ( )

Definition at line 72 of file mtk_matrix.cc.

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

Parameters

in	*in*	Given matrix.

Definition at line 91 of file mtk_matrix.cc.

16.8.2.3 mtk::Matrix::~Matrix ( )

Definition at line 110 of file mtk_matrix.cc.

16.8.3 Member Function Documentation

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

See Also

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

Returns

Absolute density of the matrix.

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

See Also

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

Returns

Absolute sparsity of the matrix.

Definition at line 182 of file mtk_matrix.cc.

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

Returns

Bandwidth of the matrix.

Definition at line 172 of file mtk_matrix.cc.

16.8.3.4 void mtk::Matrix::IncreaseNumNull ( )

Todo Review the definition of sparse matrices properties.

Definition at line 279 of file mtk_matrix.cc.

16.8.3.5 void mtk::Matrix::IncreaseNumZero ( )

Todo Review the definition of sparse matrices properties.

Definition at line 269 of file mtk_matrix.cc.

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

Returns

Number of lower diagonals.

Definition at line 162 of file mtk_matrix.cc.

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

Returns

Number of upper diagonals.

Definition at line 167 of file mtk_matrix.cc.

16.8.3.8 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 137 of file mtk_matrix.cc.

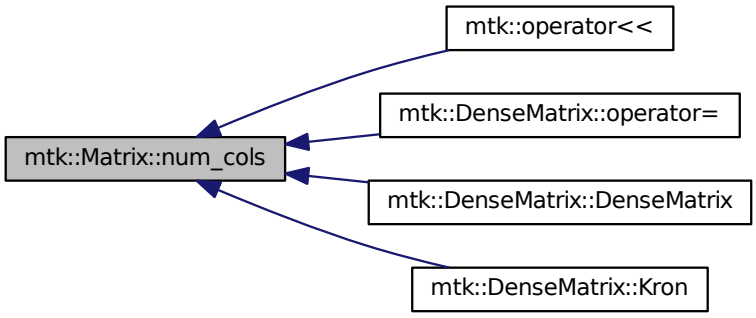
16.8.3.9 int mtk::Matrix::num_cols ( ) const

Returns

Number of rows of the matrix.

Definition at line 127 of file mtk_matrix.cc.

Here is the caller graph for this function:



16.8.3.10 int mtk::Matrix::num_non_null ( ) const

See Also

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

Returns

Number of non-null values of the matrix.

Definition at line 157 of file mtk_matrix.cc.

16.8.3.11 int mtk::Matrix::num_non_zero ( ) const

Returns

Number of non-zero values of the matrix.

Definition at line 147 of file mtk_matrix.cc.

16.8.3.12 int mtk::Matrix::num_null ( ) const

See Also

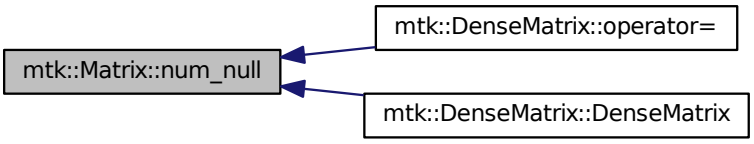
http://www.csrc.sdsu.edu/research_reports/CSRCR2013-01.pdf

Returns

Number of null values of the matrix.

Definition at line 152 of file mtk_matrix.cc.

Here is the caller graph for this function:



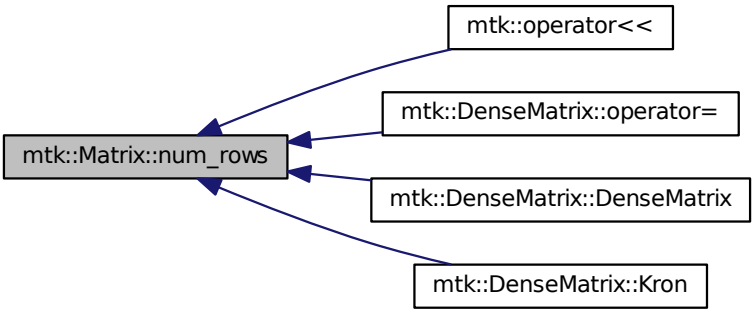
16.8.3.13 int mtk::Matrix::num_rows ( ) const

Returns

Number of rows of the matrix.

Definition at line 122 of file mtk_matrix.cc.

Here is the caller graph for this function:



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

Returns

Number of values of the matrix.

Definition at line 132 of file mtk_matrix.cc.

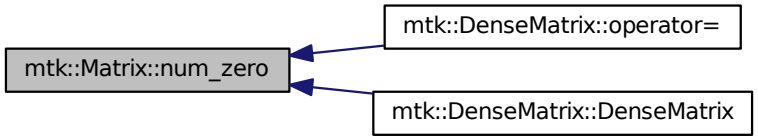
16.8.3.15 int mtk::Matrix::num_zero ( ) const

Returns

Number of zeros of the matrix.

Definition at line 142 of file mtk_matrix.cc.

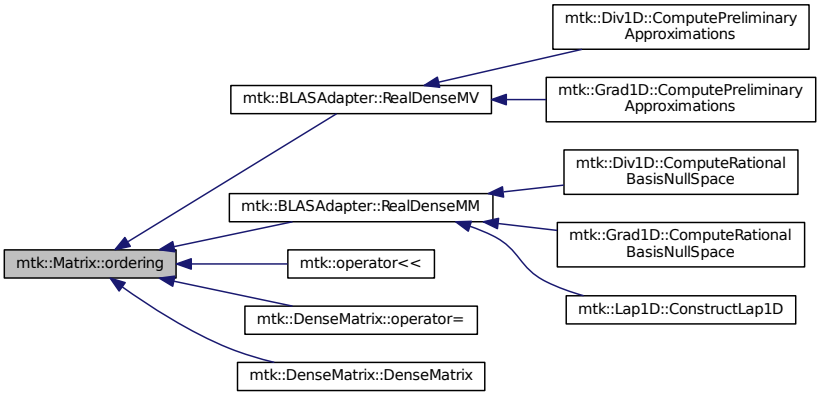
Here is the caller graph for this function:



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

Definition at line 117 of file mtk_matrix.cc.

Here is the caller graph for this function:



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

See Also

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

Returns

Relative density of the matrix.

Definition at line 177 of file mtk_matrix.cc.

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

See Also

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

Returns

Relative sparsity of the matrix.

Definition at line 187 of file mtk_matrix.cc.

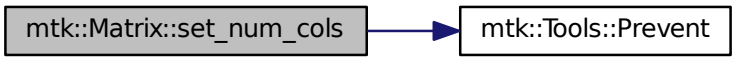
16.8.3.19 void mtk::Matrix::set_num_cols (int *num_cols*)

Parameters

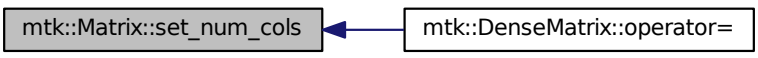
in	*num_cols*	Number of columns.

Definition at line 229 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



16.8.3.20 void mtk::Matrix::set_num_null (int *in*)

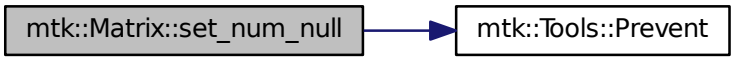
Parameters

in	*in*	Number of zero values.

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

Definition at line 255 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

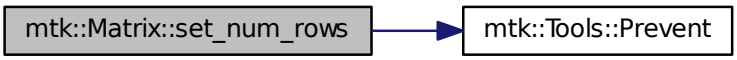
16.8.3.21 void mtk::Matrix::set_num_rows (int *num_rows*)

Parameters

in	*num_rows*	Number of rows.

Definition at line 217 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

16.8.3.22 void mtk::Matrix::set_num_zero (int *in*)

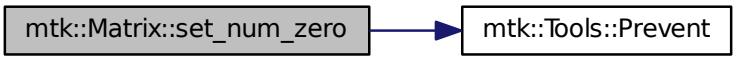
Parameters

in	*in*	Number of zero values.

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

Definition at line 241 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:

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

See Also

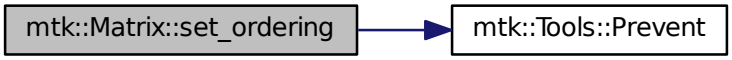
MatrixOrdering

Parameters

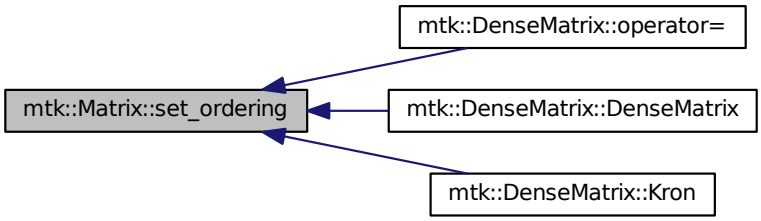
in	*oo*	Ordering of the matrix.

Definition at line 204 of file mtk_matrix.cc.

Here is the call graph for this function:



Here is the caller graph for this function:



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

See Also

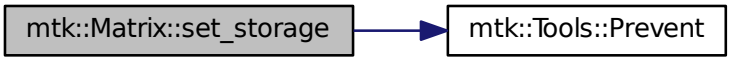
MatrixStorage

Parameters

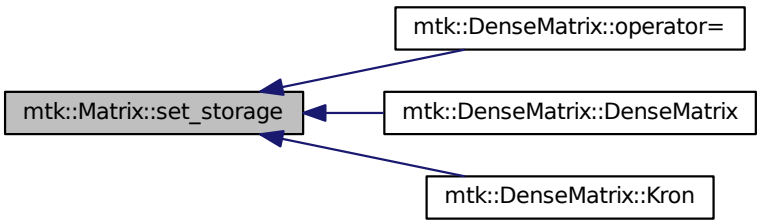
in	*tt*	Type of the matrix storage.

Definition at line 192 of file mtk_matrix.cc.

Here is the call graph for this function:



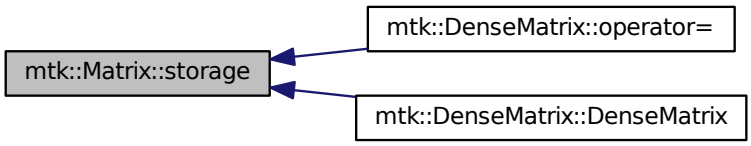
Here is the caller graph for this function:



16.8.3.25 mtk::MatrixStorage mtk::Matrix::storage ( ) const

Definition at line 112 of file mtk_matrix.cc.

Here is the caller graph for this function:



16.8.4 Member Data Documentation

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

Definition at line 288 of file mtk_matrix.h.

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

Definition at line 290 of file mtk_matrix.h.

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

Definition at line 286 of file mtk_matrix.h.

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

Definition at line 284 of file mtk_matrix.h.

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

Definition at line 285 of file mtk_matrix.h.

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

Definition at line 277 of file mtk_matrix.h.

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

Definition at line 275 of file mtk_matrix.h.

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

Definition at line 282 of file mtk_matrix.h.

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

Definition at line 280 of file mtk_matrix.h.

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

Definition at line 281 of file mtk_matrix.h.

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

Definition at line 274 of file mtk_matrix.h.

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

Definition at line 276 of file mtk_matrix.h.

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

Definition at line 279 of file mtk_matrix.h.

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

Definition at line 272 of file mtk_matrix.h.

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

Definition at line 289 of file mtk_matrix.h.

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

Definition at line 291 of file mtk_matrix.h.

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

Definition at line 270 of file mtk_matrix.h.

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

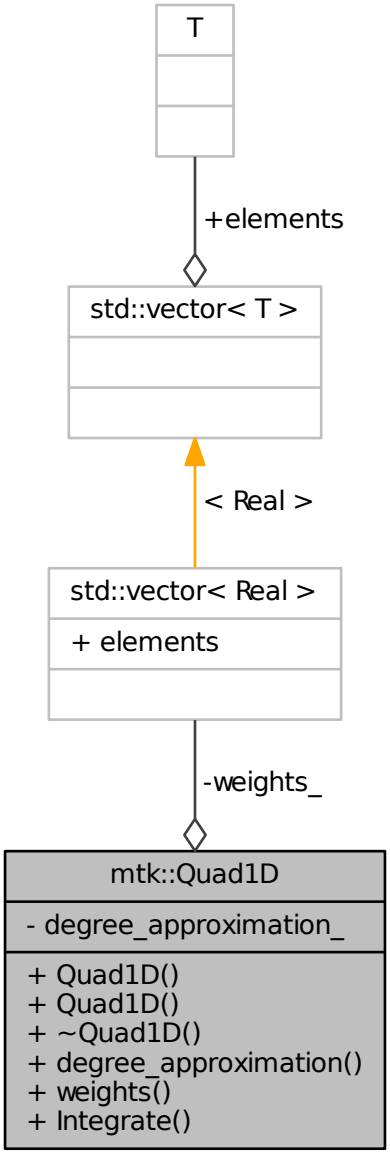
- include/mtk_matrix.h
- src/mtk_matrix.cc

16.9 mtk::Quad1D Class Reference

Implements a 1D mimetic quadrature.

`#include <mtk_quad_1d.h>`

Collaboration diagram for mtk::Quad1D:



Public Member Functions

- Quad1D ()

  Default constructor.
- Quad1D (const Quad1D &quad)

  Copy constructor.

- ~Quad1D ()
  Destructor.
- int degree_approximation () const
  Get the degree of interpolating polynomial per sub-interval of domain.
- Real * weights () const
  Return collection of weights.
- Real Integrate (Real(*Integrand)(Real xx), UniStgGrid1D grid)
  Mimetic integration routine.

Private Attributes

- int degree_approximation_
  Degree of the interpolating polynomial.
- std::vector< Real > weights_
  Collection of weights.

Friends

- std::ostream & operator<< (std::ostream &stream, Quad1D &in)
  Output stream operator for printing.

16.9.1 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.

16.9.2 Constructor & Destructor Documentation

16.9.2.1 mtk::Quad1D::Quad1D ( )

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

Parameters

in	*div*	Given quadrature.

16.9.2.3 mtk::Quad1D::~Quad1D ( )

16.9.3 Member Function Documentation

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

Returns

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

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

Parameters

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

Returns

Result of the integration.

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

Returns

Collection of weights.

16.9.4 Friends And Related Function Documentation

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

16.9.5 Member Data Documentation

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

Definition at line 124 of file mtk_quad_1d.h.

16.9.5.2 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:

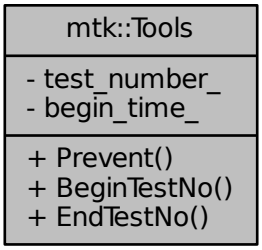
- include/mtk_quad_1d.h

16.10 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 condition, const char ∗fname, int lineno, const char ∗fxname)

  Enforces pre-conditions by preventing their complements from occur.
- static void BeginTestNo (const int &nn)

  Begins the execution of a test.
- static void EndTestNo (const int &nn)

  Ends the execution of a test.

Static Private Attributes

- static int test_number_

  Current test being executed.
- static clock_t begin_time_

  Elapsed time on current test.

16.10.1 Detailed Description

Basic tools to ensure execution correctness.

Definition at line 72 of file mtk_tools.h.

16.10.2 Member Function Documentation

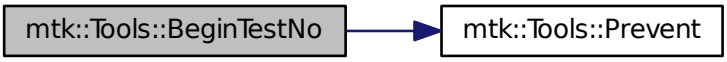
16.10.2.1 void mtk::Tools::BeginTestNo (const int & *nn*) [static]

Parameters

in	*nn*	Number of the test.

Definition at line 89 of file mtk_tools.cc.

Here is the call graph for this function:



16.10.2.2 void mtk::Tools::EndTestNo (const int & *nn*) [static]

Parameters

in	*nn*	Number of the test.

Definition at line 101 of file mtk_tools.cc.

Here is the call graph for this function:

16.10.2.3 void mtk::Tools::Prevent (const bool *condition*, const char * *fname*, int *lineno*, const char * *fxname*) [static]

See Also

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

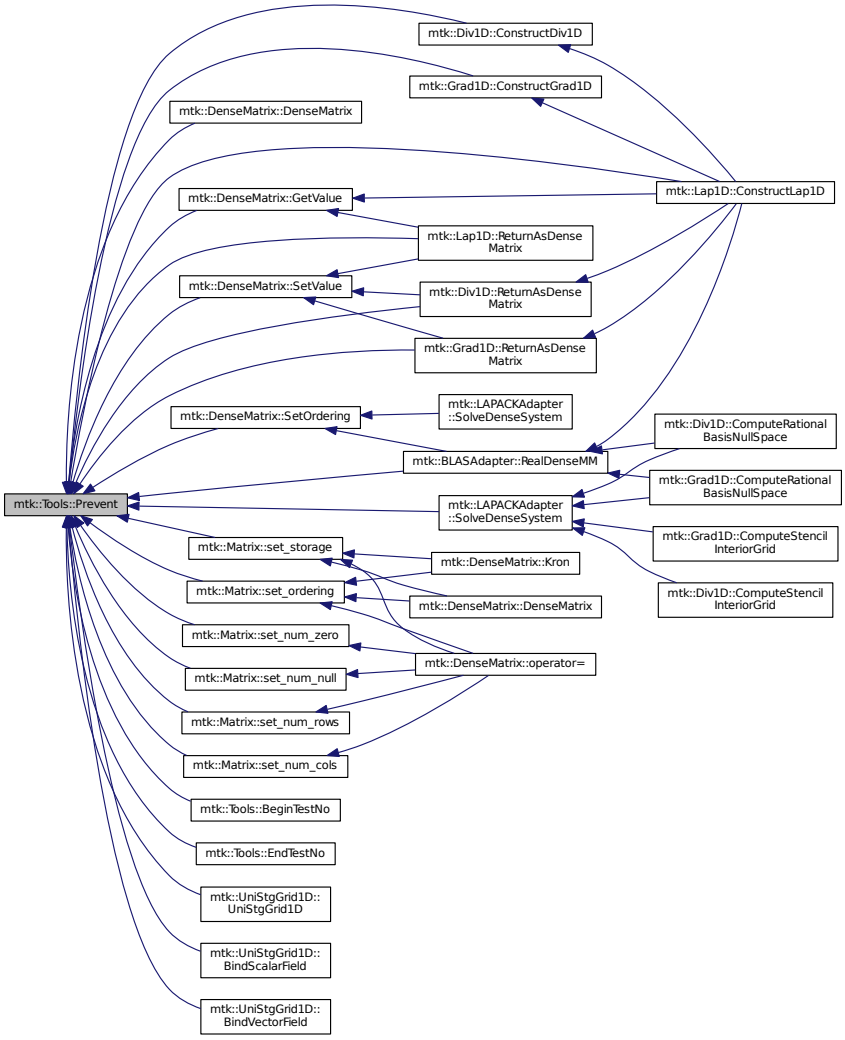
Parameters

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

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

Definition at line 61 of file mtk_tools.cc.

Here is the caller graph for this function:



16.10.3 Member Data Documentation

16.10.3.1 clock_t mtk::Tools::begin_time_ [static],[private]

Definition at line 106 of file mtk_tools.h.

16.10.3.2 int mtk::Tools::test_number_ [static],[private]

Todo Check usage of static methods and private members.

Definition at line 104 of file mtk_tools.h.

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

- include/mtk_tools.h

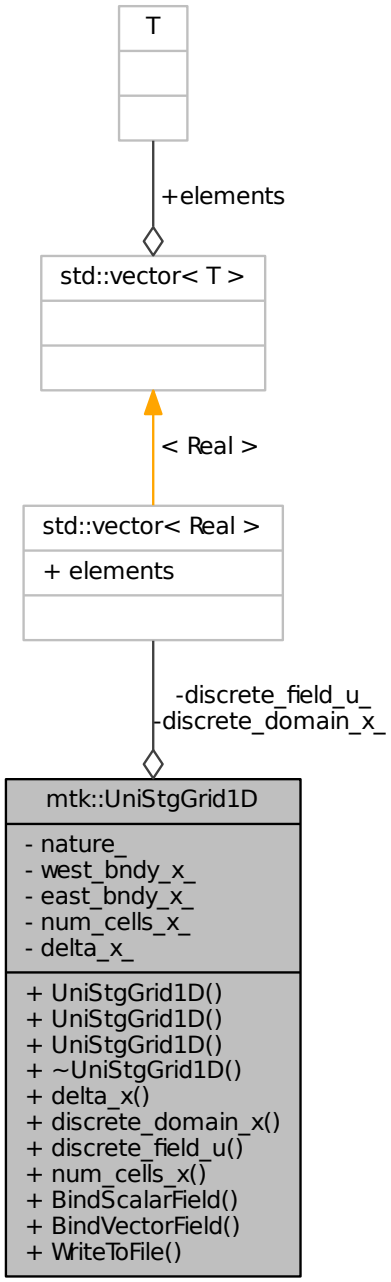
- src/mtk_tools.cc

16.11 mtk::UniStgGrid1D Class Reference

Uniform 1D Staggered Grid.

`#include <mtk_uni_stg_grid_1d.h>`

Collaboration diagram for mtk::UniStgGrid1D:



Public Member Functions

- UniStgGrid1D ()

Default constructor.

- UniStgGrid1D (const UniStgGrid1D &grid)

  Copy constructor.

- UniStgGrid1D (const Real &west_bndy_x, const Real &east_bndy_x, const int &num_cells_x, const mtk::FieldNature &nature=mtk::SCALAR)

  Construct a grid based on spatial discretization parameters.

- ~UniStgGrid1D ()

  Destructor.

- Real delta_x () const

  Provides access to the computed $ x $.

- Real * discrete_domain_x ()

  Provides access to the grid spatial data.

- Real * discrete_field_u ()

  Provides access to the grid field data.

- int num_cells_x () const

  Provides access to the number of cells of the grid.

- void BindScalarField (Real(*ScalarField)(Real xx))

  Binds a given scalar field to the grid.

- void BindVectorField (Real(*VectorField)(Real xx))

  Binds a given vector field to the grid.

- bool WriteToFile (std::string filename, std::string space_name, std::string field_name)

  Writes grid to a file compatible with Gnuplot 4.6.

Private Attributes

- FieldNature nature_

  Nature of the discrete field.

- std::vector< Real > discrete_domain_x_

  Array of spatial data.

- std::vector< Real > discrete_field_u_

  Array of field's data.

- Real west_bndy_x_

  West boundary spatial coordinate.

- Real east_bndy_x_

  East boundary spatial coordinate.

- Real num_cells_x_

  Number of cells discretizing the domain.

- Real delta_x_

  Produced Δx.

Friends

- std::ostream & operator<< (std::ostream &stream, UniStgGrid1D &in)

  Prints the grid as a tuple of arrays.

16.11.1 Detailed Description

Uniform 1D Staggered Grid.

Definition at line 77 of file mtk_uni_stg_grid_1d.h.

16.11.2 Constructor & Destructor Documentation

16.11.2.1 mtk::UniStgGrid1D::UniStgGrid1D ( )

Definition at line 97 of file mtk_uni_stg_grid_1d.cc.

16.11.2.2 mtk::UniStgGrid1D::UniStgGrid1D (const UniStgGrid1D & *grid*)

Parameters

in	*grid*	Given grid.

Definition at line 106 of file mtk_uni_stg_grid_1d.cc.

16.11.2.3 mtk::UniStgGrid1D::UniStgGrid1D (const Real & *west_bndy_x*, const Real & *east_bndy_x*, const int & *num_cells_x*, const mtk::FieldNature & *nature* = mtk::SCALAR)

Parameters

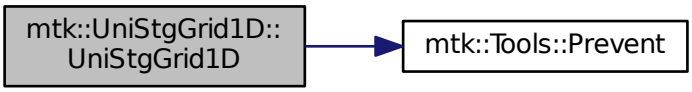
in	*west_bndy_x*	Coordinate for the west boundary.
in	*east_bndy_x*	Coordinate for the east boundary.
in	*num_cells_x*	Number of cells of the required grid.
in	*nature*	Nature of the discrete field to hold.

See Also

mtk::FieldNature

Definition at line 122 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



16.11.2.4 mtk::UniStgGrid1D::~UniStgGrid1D ( )

Definition at line 142 of file mtk_uni_stg_grid_1d.cc.

16.11.3 Member Function Documentation

16.11.3.1 void mtk::UniStgGrid1D::BindScalarField (Real(∗)(Real xx) *ScalarField*)

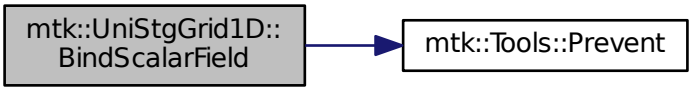
Parameters

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

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

Definition at line 164 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



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

We assume the field to be of the form:

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

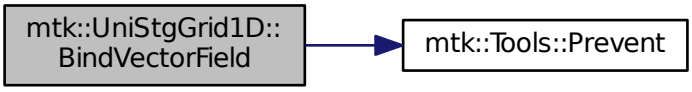
Parameters

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

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

Definition at line 200 of file mtk_uni_stg_grid_1d.cc.

Here is the call graph for this function:



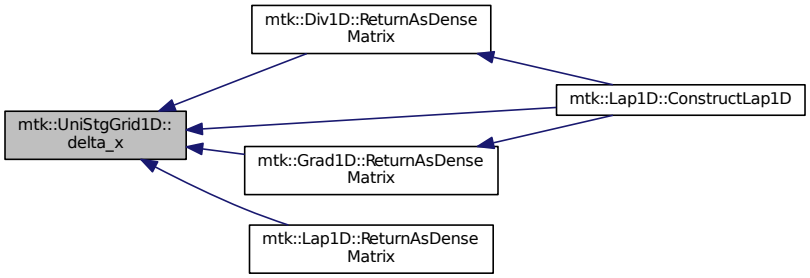
16.11.3.3 mtk::Real mtk::UniStgGrid1D::delta_x ( ) const

Returns

Computed $ x $.

Definition at line 144 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:



16.11.3.4 mtk::Real * mtk::UniStgGrid1D::discrete_domain_x ( )

Returns

Pointer to the spatial data.

Definition at line 149 of file mtk_uni_stg_grid_1d.cc.

16.11.3.5 mtk::Real * mtk::UniStgGrid1D::discrete_field_u ( )

Returns

Pointer to the field data.

Definition at line 154 of file mtk_uni_stg_grid_1d.cc.

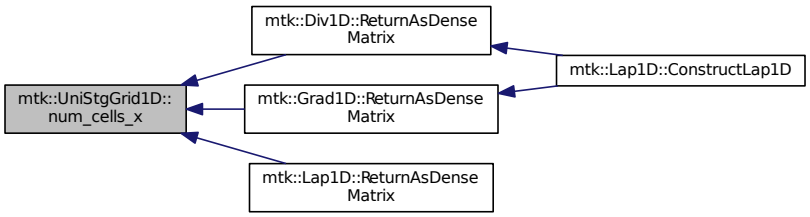
16.11.3.6 int mtk::UniStgGrid1D::num_cells_x ( ) const

Returns

Number of cells of the grid.

Definition at line 159 of file mtk_uni_stg_grid_1d.cc.

Here is the caller graph for this function:



16.11.3.7 bool mtk::UniStgGrid1D::WriteToFile (std::string *filename*, std::string *space_name*, std::string *field_name*)

Parameters

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

Returns

Success of the file writing process.

See Also

http://www.gnuplot.info/

Definition at line 228 of file mtk_uni_stg_grid_1d.cc.

16.11.4 Friends And Related Function Documentation

16.11.4.1 std::ostream& operator<< (std::ostream & *stream*, mtk::UniStgGrid1D & *in*) [friend]

1. Print spatial coordinates.

Definition at line 68 of file mtk_uni_stg_grid_1d.cc.

16.11.5 Member Data Documentation

16.11.5.1 Real mtk::UniStgGrid1D::delta_x_ [private]

Definition at line 182 of file mtk_uni_stg_grid_1d.h.

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

Definition at line 176 of file mtk_uni_stg_grid_1d.h.

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

Definition at line 177 of file mtk_uni_stg_grid_1d.h.

16.11.5.4 Real mtk::UniStgGrid1D::east_bndy_x_ [private]

Definition at line 180 of file mtk_uni_stg_grid_1d.h.

16.11.5.5 FieldNature mtk::UniStgGrid1D::nature_ [private]

Definition at line 174 of file mtk_uni_stg_grid_1d.h.

16.11.5.6 Real mtk::UniStgGrid1D::num_cells_x_ [private]

Definition at line 181 of file mtk_uni_stg_grid_1d.h.

16.11.5.7 Real mtk::UniStgGrid1D::west_bndy_x_ [private]

Definition at line 179 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

Chapter 17

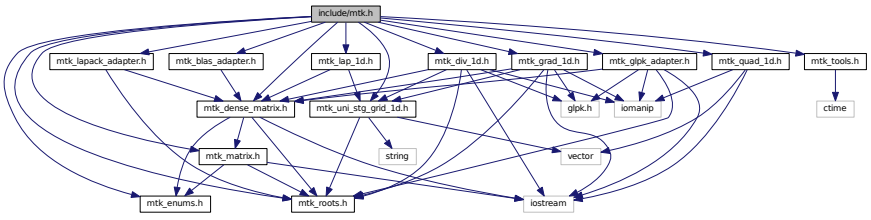
File Documentation

17.1 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_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
#include "mtk_quad_1d.h"
```

Include dependency graph for mtk.h:



17.1.1 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.

17.2 mtk.h

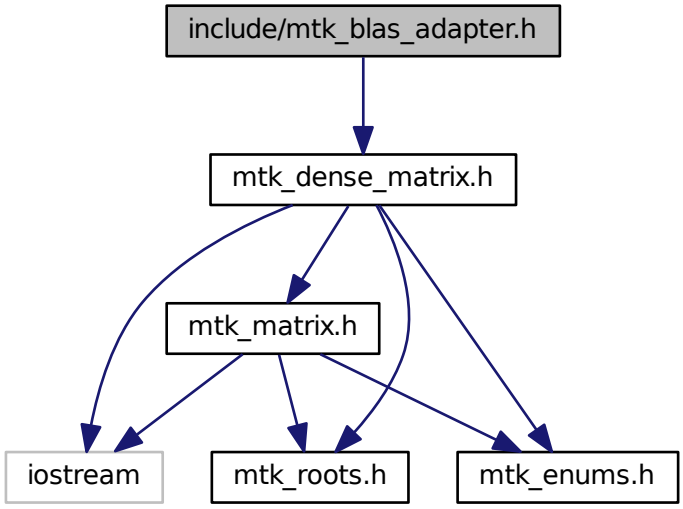
```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed. Documentation related to said modifications should be included.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions of source code must retain the above copyright notice, this
00030 list of conditions and the following disclaimer.
00031
00032 4. Redistributions in binary form must reproduce the above copyright notice,
00033 this list of conditions and the following disclaimer in the documentation and/or
00034 other materials provided with the distribution.
00035
00036 5. Usage of the binary form on proprietary applications shall require explicit
00037 prior written permission from the the copyright holders.
00038
00039 6. Neither the name of the copyright holder nor the names of its contributors
00040 may be used to endorse or promote products derived from this software without
00041 specific prior written permission.
00042
00043 The copyright holders provide no reassurances that the source code provided does
00044 not infringe any patent, copyright, or any other intellectual property rights of
00045 third parties. The copyright holders disclaim any liability to any recipient for
00046 claims brought against recipient by any third party for infringement of that
00047 parties intellectual property rights.
00048
00049 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00050 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00052 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00053 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00055 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00360 #ifndef MTK_INCLUDE_MTK_H_
00361 #define MTK_INCLUDE_MTK_H_
00362
00370 #include "mtk_roots.h"
00371
00379 #include "mtk_enums.h"
00380
00388 #include "mtk_tools.h"
00389
00397 #include "mtk_matrix.h"
00398 #include "mtk_dense_matrix.h"
00399
00407 #include "mtk_blas_adapter.h"
00408 #include "mtk_lapack_adapter.h"
```

```
00409 #include "mtk_glpk_adapter.h"
00410
00418 #include "mtk_uni_stg_grid_1d.h"
00419
00427 #include "mtk_grad_1d.h"
00428 #include "mtk_div_1d.h"
00429 #include "mtk_lap_1d.h"
00430 #include "mtk_quad_1d.h"
00431
00432 #endif // End of: MTK_INCLUDE_MTK_H_
```

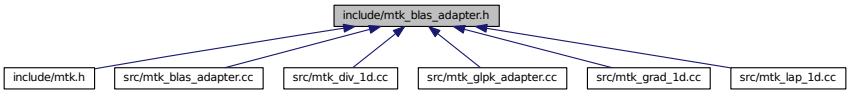
17.3 include/mtk_blas_adapter.h File Reference

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.

17.3.1 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.

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.

17.4 mtk_blas_adapter.h

```
00001
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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00032 and a copy of the modified files should be reported once modifications are
00033 completed. Documentation related to said modifications should be included.
00034
00035 2. Redistributions of source code must be done through direct
00036 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00037
00038 3. Redistributions of source code must retain the above copyright notice, this
00039 list of conditions and the following disclaimer.
00040
00041 4. Redistributions in binary form must reproduce the above copyright notice,
00042 this list of conditions and the following disclaimer in the documentation and/or
00043 other materials provided with the distribution.
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00061 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
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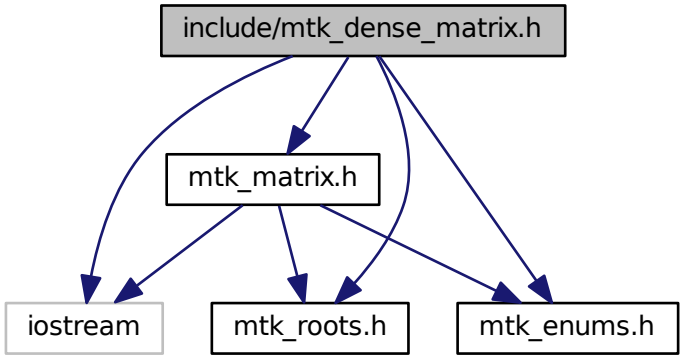
00065 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00066 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00067 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00068 */
00069
00070 #ifndef MTK_INCLUDE_BLAS_ADAPTER_H_
00071 #define MTK_INCLUDE_BLAS_ADAPTER_H_
00072
00073 #include "mtk_dense_matrix.h"
00074
00075 namespace mtk {
00076
00096 class BLASAdapter {
00097  public:
00104   static Real RealNRM2(Real *in, int &in_length);
00105
00123   static void RealDenseMV(Real &alpha,
00124                           DenseMatrix &aa,
00125                           Real *xx,
00126                           Real &beta,
00127                           Real *yy);
00128
00143   static DenseMatrix RealDenseMM(DenseMatrix &aa,
      DenseMatrix &bb);
00144 };
00145 }
00146 #endif  // End of: MTK_INCLUDE_BLAS_ADAPTER_H_
```

17.5 include/mtk_dense_matrix.h File Reference

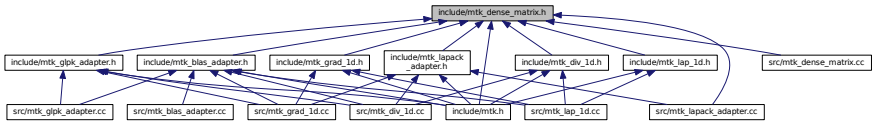
Defines a common dense matrix, using a 1D array.

```
#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.

17.5.1 Detailed Description

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

Author

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

Todo Add sparse matrices support: BANDED and CRS.

Todo Contemplate manipulation of sparse metrics.

Todo Implement Kronecker product using the BLAS.

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.

17.6 mtk_dense_matrix.h

```
00001
00029 /*
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00031 University. All rights reserved.
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00034 are permitted provided that the following conditions are met:
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00037 and a copy of the modified files should be reported once modifications are
00038 completed. Documentation related to said modifications should be included.
00039
00040 2. Redistributions of source code must be done through direct
00041 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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```

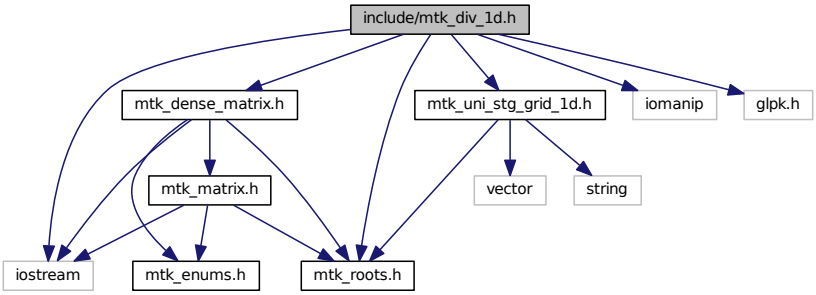
```
00072 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00073 */
00074
00075 #ifndef MTK_INCLUDE_DENSE_MATRIX_H_
00076 #define MTK_INCLUDE_DENSE_MATRIX_H_
00077
00078 #include <iostream>
00079
00080 #include "mtk_roots.h"
00081 #include "mtk_enums.h"
00082 #include "mtk_matrix.h"
00083
00084 namespace mtk {
00085
00098 class DenseMatrix {
00099  public:
00101   friend std::ostream& operator <<(std::ostream &stream, DenseMatrix &in);
00102
00104   DenseMatrix& operator =(const DenseMatrix &in);
00105
00107   DenseMatrix();
00108
00114   DenseMatrix(const DenseMatrix &in);
00115
00124   DenseMatrix(const int &num_rows, const int &num_cols);
00125
00151   DenseMatrix(const int &rank, const bool &padded, const bool &transpose);
00152
00186   DenseMatrix(const Real *gen,
00187               const int &gen_length,
00188               const int &pro_length,
00189               const bool &transpose);
00190
00192   ~DenseMatrix();
00193
00199   Matrix matrix_properties() const;
00200
00206   int num_rows() const;
00207
00213   int num_cols() const;
00214
00220   Real* data() const;
00221
00229   void SetOrdering(mtk::MatrixOrdering oo);
00230
00239   Real GetValue(const int &row_coord, const int &col_coord) const;
00240
00248   void SetValue(const int &row_coord,
00249                 const int &col_coord,
00250                 const Real &val);
00251
00253   void Transpose();
00254
00256   void OrderRowMajor();
00257
00259   void OrderColMajor();
00260
00269   static DenseMatrix Kron(const DenseMatrix &aa, const
      DenseMatrix &bb);
00270
00271  private:
00272   Matrix matrix_properties_;
00273
00274   Real *data_;
00275 };
00276 }
00277 #endif  // End of: MTK_INCLUDE_MTK_DENSE_MATRIX_H_
```

17.7 include/mtk_div_1d.h File Reference

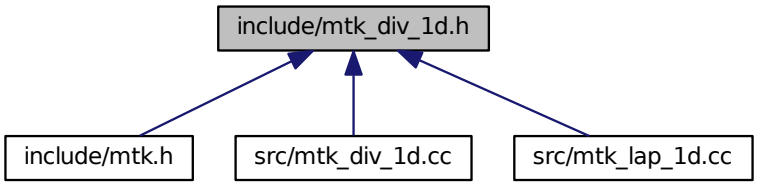
Includes the definition of the class Div1D.

```
#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.

17.7.1 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.

17.8 mtk_div_1d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed. Documentation related to said modifications should be included.
00021
00022 2. Redistributions of source code must be done through direct
00023 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00025 3. Redistributions of source code must retain the above copyright notice, this
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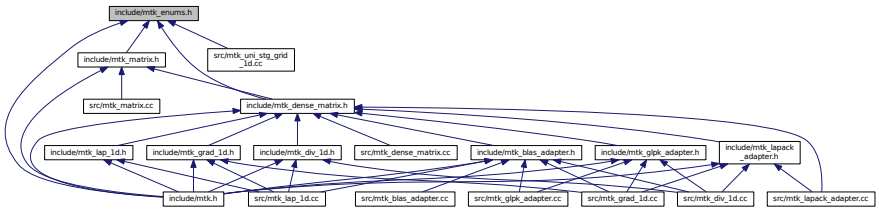
00052 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00053 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00054 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00055 */
00056
00057 #ifndef MTK_INCLUDE_DIV_1D_H_
00058 #define MTK_INCLUDE_DIV_1D_H_
00059
00060 #include <iostream>
00061 #include <iomanip>
00062
00063 #include "glpk.h"
00064
00065 #include "mtk_roots.h"
00066 #include "mtk_dense_matrix.h"
00067 #include "mtk_uni_stg_grid_1d.h"
00068
00069 namespace mtk {
```

```
00070
00081 class Div1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Div1D &in);
00085
00087   Div1D();
00088
00094   Div1D(const Div1D &div);
00095
00097   ~Div1D();
00098
00104   bool ConstructDiv1D(int order_accuracy = kDefaultOrderAccuracy,
00105                       Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112   Real* weights_crs(void);
00113
00119   Real* weights_cbs(void);
00120
00126   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid);
00127
00128  private:
00134   bool ComputeStencilInteriorGrid(void);
00135
00142   bool ComputeRationalBasisNullSpace(void);
00143
00149   bool ComputePreliminaryApproximations(void);
00150
00156   bool ComputeWeights(void);
00157
00163   bool ComputeStencilBoundaryGrid(void);
00164
00170   bool AssembleOperator(void);
00171
00172   int order_accuracy_;
00173   int dim_null_;
00174   int num_bndy_coeffs_;
00175   int divergence_length_;
00176
00177   int minrow_;
00178   int row_;
00179
00180   mtk::DenseMatrix rat_basis_null_space_;
00181
00182   Real *coeffs_interior_;
00183   Real *prem_apps_;
00184   Real *weights_crs_;
00185   Real *weights_cbs_;
00186   Real *mim_bndy_;
00187   Real *divergence_;
00188
00189   Real mimetic_threshold_;
00190 };
00191 }
00192 #endif  // End of: MTK_INCLUDE_DIV_1D_H_
```

17.9 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.

17.9.1 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.

17.10 mtk_enums.h

```
00001
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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. Documentation related to said modifications should be included.
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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00053 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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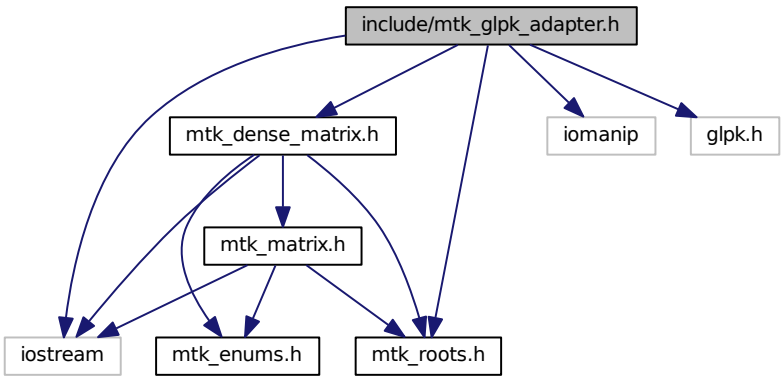
00055 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00056 */
00057
00058 #ifndef MTK_INCLUDE_ENUMS_H_
00059 #define MTK_INCLUDE_ENUMS_H_
00060
00061 namespace mtk {
00062
00077 enum MatrixStorage {
00078   DENSE,
00079   BANDED,
00080   CRS
00081 };
00082
00095 enum MatrixOrdering {
00096   ROW_MAJOR,
00097   COL_MAJOR
00098 };
00099
00113 enum FieldNature {
00114   SCALAR,
00115   VECTOR
00116 };
00117 }
00118 #endif  // End of: MTK_INCLUDE_ENUMS_H_
```

17.11 include/mtk_glpk_adapter.h File Reference

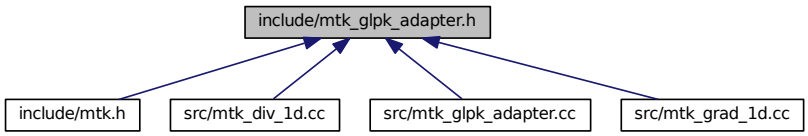
Adapter class for the GLPK API.

```
#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.

17.11.1 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 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.

17.12 mtk_glpk_adapter.h

```
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00019 /*
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00021 University. All rights reserved.
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00024 are permitted provided that the following conditions are met:
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00027 and a copy of the modified files should be reported once modifications are
```

```
00028 completed. Documentation related to said modifications should be included.
00029
00030 2. Redistributions of source code must be done through direct
00031 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00034 list of conditions and the following disclaimer.
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00037 this list of conditions and the following disclaimer in the documentation and/or
00038 other materials provided with the distribution.
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00060 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
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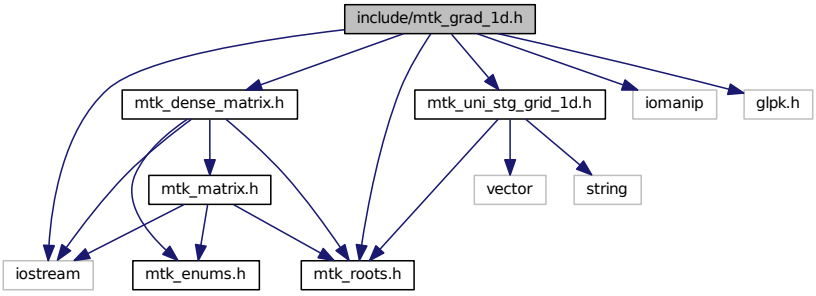
00063 */
00064
00065 #ifndef MTK_INCLUDE_GLPK_ADAPTER_H_
00066 #define MTK_INCLUDE_GLPK_ADAPTER_H_
00067
00068 #include <iostream>
00069 #include <iomanip>
00070
00071 #include "glpk.h"
00072
00073 #include "mtk_roots.h"
00074 #include "mtk_dense_matrix.h"
00075
00076 namespace mtk {
00077
00101 class GLPKAdapter {
00102  public:
00121   static mtk::Real SolveSimplexAndCompare(
      mtk::Real *A,
00122                                           int nrows,
00123                                           int ncols,
00124                                           int kk,
00125                                           mtk::Real *hh,
00126                                           mtk::Real *qq,
00127                                           int robjective,
00128                                           mtk::Real mimetic_tol,
00129                                           int copy);
00130 };
00131 }
00132 #endif  // End of: MTK_INCLUDE_MTK_GLPK_ADAPTER_H_
```

17.13 include/mtk_grad_1d.h File Reference

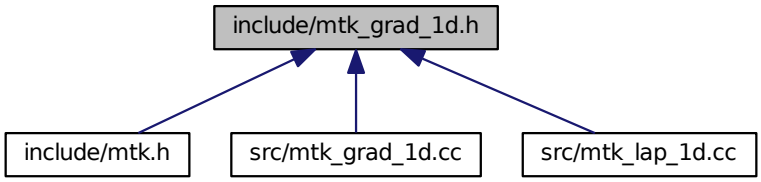
Includes the definition of the class Grad1D.

```
#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.

17.13.1 Detailed Description

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

Author

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

Definition in file mtk_grad_1d.h.

17.14 mtk_grad_1d.h

```
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00011 /*
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00013 University. All rights reserved.
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00016 are permitted provided that the following conditions are met:
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00019 and a copy of the modified files should be reported once modifications are
00020 completed. Documentation related to said modifications should be included.
00021
00022 2. Redistributions of source code must be done through direct
00023 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00024
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00026 list of conditions and the following disclaimer.
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00029 this list of conditions and the following disclaimer in the documentation and/or
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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 {
```

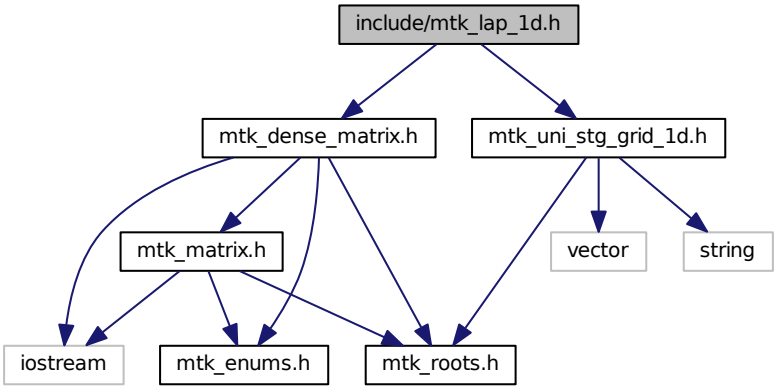
```
00070
00081 class Grad1D {
00082  public:
00084   friend std::ostream& operator <<(std::ostream& stream, Grad1D &in);
00085
00087   Grad1D();
00088
00094   Grad1D(const Grad1D &grad);
00095
00097   ~Grad1D();
00098
00104   bool ConstructGrad1D(int order_accuracy = kDefaultOrderAccuracy,
00105                        Real mimetic_threshold = kDefaultMimeticThreshold);
00106
00112   Real* weights_crs(void);
00113
00119   Real* weights_cbs(void);
00120
00126   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid);
00127
00128  private:
00134   bool ComputeStencilInteriorGrid(void);
00135
00142   bool ComputeRationalBasisNullSpace(void);
00143
00149   bool ComputePreliminaryApproximations(void);
00150
00156   bool ComputeWeights(void);
00157
00163   bool ComputeStencilBoundaryGrid(void);
00164
00170   bool AssembleOperator(void);
00171
00172   int order_accuracy_;
00173   int dim_null_;
00174   int num_bndy_approxs_;
00175   int num_bndy_coeffs_;
00176   int gradient_length_;
00177
00178   int minrow_;
00179   int row_;
00180
00181   mtk::DenseMatrix rat_basis_null_space_;
00182
00183   Real *coeffs_interior_;
00184   Real *prem_apps_;
00185   Real *weights_crs_;
00186   Real *weights_cbs_;
00187   Real *mim_bndy_;
00188   Real *gradient_;
00189
00190   Real mimetic_threshold_;
00191 };
00192 }
00193 #endif  // End of: MTK_INCLUDE_GRAD_1D_H_
```

17.15 include/mtk_lap_1d.h File Reference

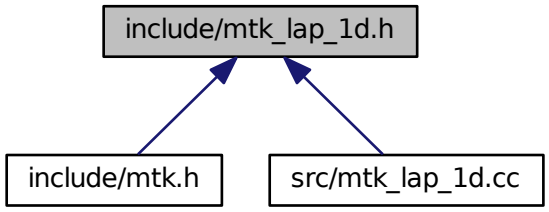
Includes the definition of the class Lap1D.

```
#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.

17.15.1 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.

17.16 mtk_lap_1d.h

```
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00019 and a copy of the modified files should be reported once modifications are
00020 completed. Documentation related to said modifications should be included.
00021
00022 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
00076 class Lap1D {
00077  public:
00079   friend std::ostream& operator <<(std::ostream& stream, Lap1D &in);
00080
```

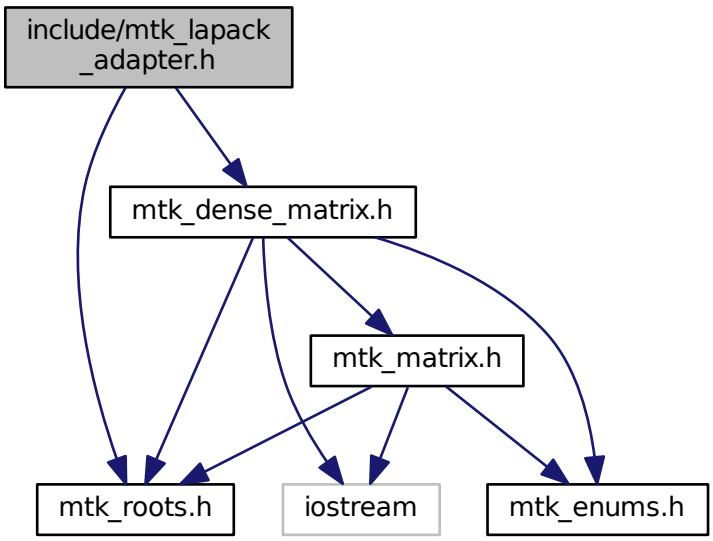
```
00082   Lap1D();
00083
00089   Lap1D(const Lap1D &lap);
00090
00092   ~Lap1D();
00093
00099   bool ConstructLap1D(int order_accuracy = kDefaultOrderAccuracy,
00100                       Real mimetic_threshold = kDefaultMimeticThreshold);
00101
00107   DenseMatrix ReturnAsDenseMatrix(const
      UniStgGrid1D &grid);
00108
00114   mtk::Real* Data(const UniStgGrid1D &grid);
00115
00116  private:
00117   int order_accuracy_;
00118   int laplacian_length_;
00119
00120   Real *laplacian_;
00121
00122   Real mimetic_threshold_;
00123 };
00124 }
00125 #endif  // End of: MTK_INCLUDE_LAP_1D_H_
```

17.17 include/mtk_lapack_adapter.h File Reference

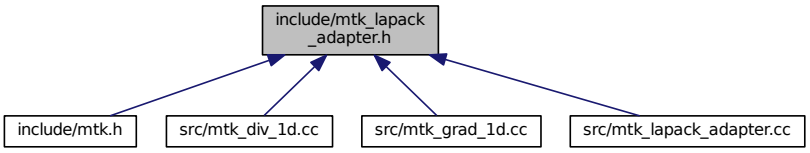
Adapter class for the LAPACK API.

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

17.17.1 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** 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.

17.18 mtk_lapack_adapter.h

```
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00026 and a copy of the modified files should be reported once modifications are
00027 completed. Documentation related to said modifications should be included.
```

```
00028
00029 2. Redistributions of source code must be done through direct
00030 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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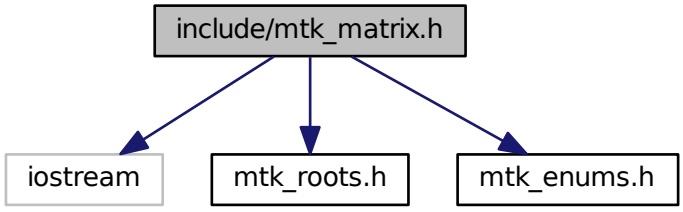
00061 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00062 */
00063
00064 #ifndef MTK_INCLUDE_LAPACK_ADAPTER_H_
00065 #define MTK_INCLUDE_LAPACK_ADAPTER_H_
00066
00067 #include "mtk_roots.h"
00068 #include "mtk_dense_matrix.h"
00069
00070 namespace mtk {
00071
00089 class LAPACKAdapter {
00090  public:
00101   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00102                               mtk::Real *rhs);
00103
00114   static int SolveDenseSystem(mtk::DenseMatrix &mm,
00115                               mtk::DenseMatrix &rr);
00116
00128   static int SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00129                                          mtk::Real *ob_,
00130                                          int ob_ld_);
00131
00143   static mtk::DenseMatrix QRFactorDenseMatrix(
      DenseMatrix &matrix);
00144 };
00145 }
00146 #endif  // End of: MTK_INCLUDE_LAPACK_ADAPTER_H_
```

17.19 include/mtk_matrix.h File Reference

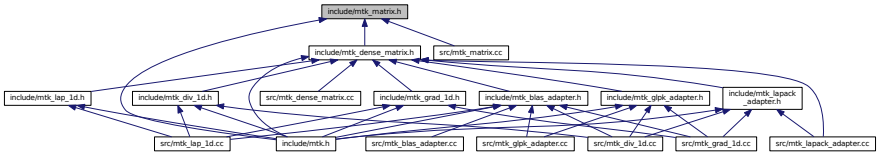
Definition of the representation of a matrix in the MTK.

```
#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.

17.19.1 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.

17.20 mtk_matrix.h

```
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00010 /*
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00018 and a copy of the modified files should be reported once modifications are
00019 completed. Documentation related to said modifications should be included.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00054 */
00055
00056 #ifndef MTK_INCLUDE_MATRIX_H_
00057 #define MTK_INCLUDE_MATRIX_H_
00058
00059 #include <iostream>
00060
00061 #include "mtk_roots.h"
00062 #include "mtk_enums.h"
00063
00064 namespace mtk {
00065
00075 class Matrix {
00076  public:
00078   Matrix();
00079
00085   Matrix(const Matrix &in);
00086
00088   ~Matrix();
00089
00091   MatrixStorage storage() const;
00092
00094   MatrixOrdering ordering() const;
00095
00101   int num_rows() const;
00102
00108   int num_cols() const;
00109
00115   int num_values() const;
00116
00126   int ld() const;
00127
00133   int num_zero() const;
```

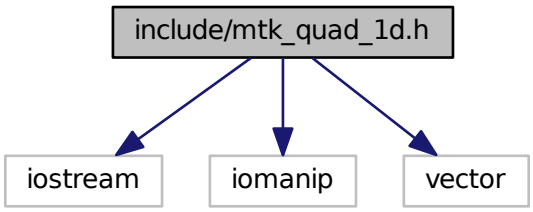
```
00134
00140   int num_non_zero() const;
00141
00149   int num_null() const;
00150
00158   int num_non_null() const;
00159
00165   int kl() const;
00166
00172   int ku() const;
00173
00179   int bandwidth() const;
00180
00188   Real abs_density() const;
00189
00197   Real rel_density() const;
00198
00206   Real abs_sparsity() const;
00207
00215   Real rel_sparsity() const;
00216
00224   void set_storage(const MatrixStorage &tt);
00225
00233   void set_ordering(const MatrixOrdering &oo);
00234
00240   void set_num_rows(int num_rows);
00241
00247   void set_num_cols(int num_cols);
00248
00254   void set_num_zero(int in);
00255
00261   void set_num_null(int in);
00262
00264   void IncreaseNumZero();
00265
00267   void IncreaseNumNull();
00268
00269  private:
00270   MatrixStorage storage_;
00271
00272   MatrixOrdering ordering_;
00273
00274   int num_rows_;
00275   int num_cols_;
00276   int num_values_;
00277   int ld_;
00278
00279   int num_zero_;
00280   int num_non_zero_;
00281   int num_null_;
00282   int num_non_null_;
00283
00284   int kl_;
00285   int ku_;
00286   int bandwidth_;
00287
00288   Real abs_density_;
00289   Real rel_density_;
00290   Real abs_sparsity_;
00291   Real rel_sparsity_;
00292 };
00293 }
00294 #endif  // End of: MTK_INCLUDE_MATRIX_H_
```

17.21 include/mtk_quad_1d.h File Reference

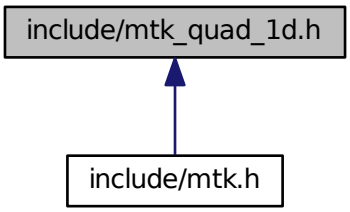
Includes the definition of the class Quad1D.

```
#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.

17.21.1 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.

17.22 mtk_quad_1d.h

```
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00024 completed. Documentation related to said modifications should be included.
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00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00029 3. Redistributions of source code must retain the above copyright notice, this
00030 list of conditions and the following disclaimer.
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00033 this list of conditions and the following disclaimer in the documentation and/or
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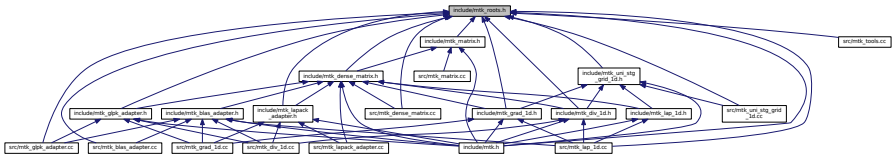
00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #ifndef MTK_INCLUDE_QUAD_1D_H_
00062 #define MTK_INCLUDE_QUAD_1D_H_
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);
00122
00123  private:
00124   int degree_approximation_;
00125
00126   std::vector<Real> weights_;
00127 };
00128 }
00129 #endif  // End of: MTK_INCLUDE_QUAD_1D_H_
```

17.23 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 {1.e-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.

17.23.1 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 mechanism.

Definition in file mtk_roots.h.

17.24 mtk_roots.h

```
00001
00017 /*
00018 Copyright (C) 2015, Computational Science Research Center, San Diego State
00019 University. All rights reserved.
00020
00021 Redistribution and use in source and binary forms, with or without modification,
00022 are permitted provided that the following conditions are met:
00023
00024 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00025 and a copy of the modified files should be reported once modifications are
00026 completed. Documentation related to said modifications should be included.
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 of source code must retain the above copyright notice, this
00032 list of conditions and the following disclaimer.
00033
00034 4. Redistributions in binary form must reproduce the above copyright notice,
00035 this list of conditions and the following disclaimer in the documentation and/or
00036 other materials provided with the distribution.
00037
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00044
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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
```

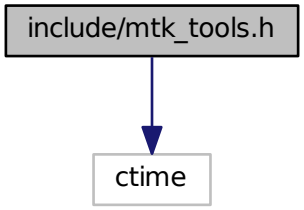
```
00060 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00061 */
00062
00063 #ifndef MTK_INCLUDE_ROOTS_H_
00064 #define MTK_INCLUDE_ROOTS_H_
00065
00071 namespace mtk {
00072
00080 #ifdef MTK_PRECISION_DOUBLE
00081 typedef double Real;
00082 #else
00083 typedef float Real;
00084 #endif
00085
00103 #ifdef MTK_PRECISION_DOUBLE
00104 const double kZero{0.0};
00105 const double kOne{1.0};
00106 #else
00107 const float kZero{0.0f};
00108 const float kOne{1.0f};
00109 #endif
00110
00118 #ifdef MTK_PRECISION_DOUBLE
00119 const double kDefaultTolerance{1e-7};
00120 #else
00121 const float kDefaultTolerance{1e-7f};
00122 #endif
00123
00133 const int kDefaultOrderAccuracy{2};
00134
00144 #ifdef MTK_PRECISION_DOUBLE
00145 const double kDefaultMimeticThreshold{1.e-6};
00146 #else
00147 const float kDefaultMimeticThreshold{1.e-6f};
00148 #endif
00149
00157 const int kCriticalOrderAccuracyDiv{8};
00158
00166 const int kCriticalOrderAccuracyGrad{10};
00167 }
00168 #endif  // End of: MTK_INCLUDE_ROOTS_H_
```

17.25 include/mtk_tools.h File Reference

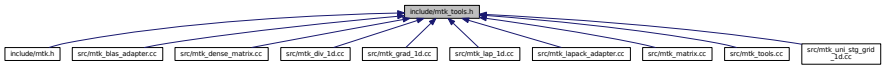
Tool manager class.

`#include <ctime>`

Include dependency graph for mtk_tools.h:



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



Classes

- class mtk::Tools

  Tool manager class.

Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

17.25.1 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.h.

17.26 mtk_tools.h

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed. Documentation related to said modifications should be included.
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 of source code must retain the above copyright notice, this
00025 list of conditions and the following disclaimer.
00026
00027 4. 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 5. Usage of the binary form on proprietary applications shall require explicit
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00034 6. Neither the name of the copyright holder nor the names of its contributors
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00036 specific prior written permission.
00037
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```

```
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00042 parties intellectual property rights.
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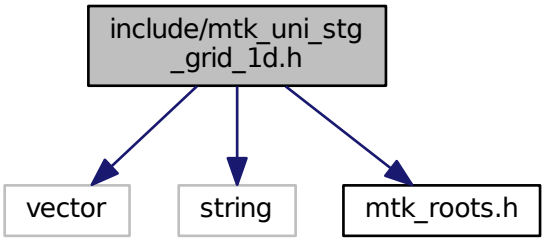
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #ifndef MTK_INCLUDE_TOOLS_H_
00057 #define MTK_INCLUDE_TOOLS_H_
00058
00059 #include <ctime>
00060
00061 namespace mtk {
00062
00072 class Tools {
00073  public:
00084   static void Prevent(const bool condition,
00085                       const char *fname,
00086                       int lineno,
00087                       const char *fxname);
00088
00094   static void BeginTestNo(const int &nn);
00095
00101   static void EndTestNo(const int &nn);
00102
00103  private:
00104   static int test_number_;
00105
00106   static clock_t begin_time_;
00107 };
00108 }
00109 #endif  // End of: MTK_INCLUDE_TOOLS_H_
```

17.27 include/mtk_uni_stg_grid_1d.h File Reference

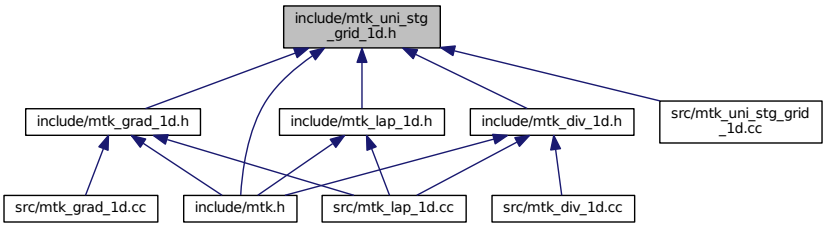
Definition of an 1D uniform staggered grid.

```
#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.

17.27.1 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.

17.28 mtk_uni_stg_grid_1d.h

```
00001
00012 /*
00013 Copyright (C) 2015, Computational Science Research Center, San Diego State
00014 University. All rights reserved.
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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. Documentation related to said modifications should be included.
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 of source code must retain the above copyright notice, this
00027 list of conditions and the following disclaimer.
```

```
00028
00029 4. Redistributions in binary form must reproduce the above copyright notice,
00030 this list of conditions and the following disclaimer in the documentation and/or
00031 other materials provided with the distribution.
00032
00033 5. Usage of the binary form on proprietary applications shall require explicit
00034 prior written permission from the the copyright holders.
00035
00036 6. 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
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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 delta_x() const;
00116
00122   Real *discrete_domain_x();
00123
00129   Real *discrete_field_u();
00130
00136   int num_cells_x() const;
00137
00143   void BindScalarField(Real (*ScalarField)(Real xx));
00144
00156   void BindVectorField(Real (*VectorField)(Real xx));
00157
00169   bool WriteToFile(std::string filename,
00170                    std::string space_name,
00171                    std::string field_name);
00172
00173  private:
00174   FieldNature nature_;
00175
00176   std::vector<Real> discrete_domain_x_;
00177   std::vector<Real> discrete_field_u_;
00178
00179   Real west_bndy_x_;
00180   Real east_bndy_x_;
00181   Real num_cells_x_;
00182   Real delta_x_;
```

```
00183 };
00184 }
00185 #endif  // End of: MTK_INCLUDE_UNI_STG_GRID_1D_H_
```

17.29 Makefile.inc File Reference

17.30 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.
00008 #   ____________________________________________________________________
00009
00010 BASE = $(HOME)/Dropbox/MTK
00011
00012 #   2. The machine (platform) identifier and required precision.
00013 #   ____________________________________________________________________
00014
00015 # Options are:
00016 # - LINUX: A LINUX box installation.
00017 # - OSX: Soon!
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 # Options are ON xor OFF:
00031
00032 ATL_OPT = OFF
00033
00034 #   4. Paths to dependencies (header files for compiling).
00035 #   ____________________________________________________________________
00036
00037 # GLPK include path (soon to go):
00038
00039 GLPK_INC = $(HOME)/Libraries/glpk-4.55/include
00040
00041 # If ATLAS optimization is ON, users should only provide the path to ATLAS:
00042
00043 ATLAS_INC = $(HOME)/Libraries/ATLAS_3.8.4-CORE/include
00044
00045 #   5. Paths to dependencies (archive files for (static) linking).
00046 #   ____________________________________________________________________
00047
00048 # GLPK linking path (soon to go):
00049
00050 GLPK_LIB = $(HOME)/Libraries/glpk-4.55/lib/libglpk.a
00051
00052 # If optimization is OFF, then provide the paths for:
00053
00054 BLAS_LIB = $(HOME)/Libraries/BLAS/libblas.a
00055 LAPACK_LIB = $(HOME)/Libraries/lapack-3.4.1/liblapack.a
00056
00057 # WARNING: Vendor libraries should be used whenever they are available.
00058
00059 # However, if optimization is ON, please provide the path the ATLAS' archive:
00060
00061 ATLAS_LIB   = $(HOME)/Libraries/ATLAS_3.8.4-CORE/ATLAS_3.8.4-BUILD-Citadel/lib
00062
00063 #   6. Compiler and its flags.
00064 #   ____________________________________________________________________
00065
00066 CC = colorgcc
00067
```

```
00068 # Debug Level. Options are:
00069 # 0. NO debug at all NOR any run-time checks... be cautious!
00070 # 1. Verbose (execution messages) AND run-time checks.
00071 # 2. Level 1 plus intermediate scalar-valued results.
00072 # 3. Level 2 plus intermediate array-valued results.
00073
00074 DEBUG_LEVEL = 3
00075
00076 # Flags recommended for release code:
00077
00078 CCFLAGS = -Wall -O2
00079
00080 # Flags recommended for debugging code:
00081
00082 CCFLAGS = -Wall -g
00083
00084 #   7. Archiver, its flags, and ranlib:
00085 #   ____________________________________________________________________
00086
00087 ARCH      = ar
00088 ARCHFLAGS = cr
00089
00090 # If your system does not have "ranlib" then set: "RANLIB = echo":
00091
00092 RANLIB = echo
00093
00094 # But, if possible:
00095
00096 RANLIB = ranlib
00097
00098 #   8. Valgrind's memcheck options:
00099 #   ____________________________________________________________________
00100
00101 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00102 --track-origins=yes --freelist-vol=20000000
00103
00104 # Done!
00105
00106 #   ____________________________________________________________________
00107 #   ____________________________________________________________________
00108 #   ____________________________________________________________________
00109
00110 #   MTK-related.
00111 #   ____________________________________________________________________
00112
00113 SRC       = $(BASE)/src
00114 INCLUDE   = $(BASE)/include
00115 LIB       = $(BASE)/lib
00116 MTK_LIB   = $(LIB)/libmtk.a
00117 TESTS     = $(BASE)/tests
00118 EXAMPLES  = $(BASE)/examples
00119
00120 #   Compiling-related.
00121 #   ____________________________________________________________________
00122
00123 CCFLAGS += -std=c++11 -fPIC -DMTK_DEBUG_LEVEL=$(DEBUG_LEVEL) -I$(INCLUDE)  -c
00124
00125 ifeq ($(PRECISION),DOUBLE)
00126   CCFLAGS += -DMTK_PRECISION_DOUBLE
00127 else
00128   CCFLAGS += -DMTK_PRECISION_SINGLE
00129 endif
00130
00131 # Only the GLPK is included because the other dependencies are coded in Fortran.
00132
00133 ifeq ($(ATL_OPT),ON)
00134   CCFLAGS  += -I$(GLPK_INC) $(ATLAS_INC)
00135 else
00136   CCFLAGS  += -I$(GLPK_INC)
00137 endif
00138
00139 #   Linking-related.
00140 #   ____________________________________________________________________
00141
00142 NOOPT_LIBS  = $(LAPACK_LIB) $(BLAS_LIB) -lm $(GLPK_LIB) -lstdc++
00143
00144 OPT_LIBS    = -L$(ATLAS_LIB) -latlas -llapack -lblas -lm -latlas -lstdc++
00145
00146 ifeq ($(PLAT),MACOS)
00147   LINKER  = g++
00148   LINKER  += -framework Accelerate $(GLPK_LIB) $(MTK_LIB)
```

```
00149 else
00150   ifeq ($(ATL_OPT),ON)
00151     LINKER  = g++
00152     LIBS = $(MTK_LIB)
00153     LIBS += $(OPT_LIBS)
00154   else
00155     LINKER  = gfortran
00156     LIBS = $(MTK_LIB)
00157     LIBS += $(NOOPT_LIBS)
00158   endif
00159 endif
00160
00161 #   Documentation-related.
00162 #   ------------------------------------------------------------------
00163
00164 DOCGEN      = doxygen
00165 DOCFILENAME = doc_config.dxcf
00166 DOC         = $(BASE)/doc
00167 DOCFILE     = $(BASE)/$(DOCFILENAME)
```

17.31 README.md File Reference

17.32 README.md

```
00001 # README File for 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 discretization** methods for the
00014 numerical solution of ordinary and partial differential equations.
00015     ------------------------------------------------------------------
00016
00017 ## 2. Dependencies
00018
00019 This README assumes all of these dependencies are installed in the following
00020 folder:
00021
00022 ```
00023 $(HOME)/Libraries/
00024 ```
00025
00026 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00027 routines for the internal computation on some of the layers. However, ATLAS
00028 requires both BLAS and LAPACK in order to create their optimized distributions.
00029 Therefore, the following dependencies tree arises:
00030
00031 ### For Linux:
00032
00033 1. LAPACK - Available from: http://www.netlib.org/lapack/
00034   1. BLAS - Available from: http://www.netlib.org/blas/
00035
00036 2. (Optional) ATLAS - Available from: http://math-atlas.sourceforge.net/
00037   1. BLAS - Available from: http://www.netlib.org/blas/
00038   2. LAPACK - Available from: http://www.netlib.org/lapack/
00039
00040 3. (Optional) Valgrind - Available from: http://valgrind.org/
00041
00042 4. (Optional) Doxygen - Available from http://www.stack.nl/~dimitri/doxygen/
00043
00044 ### For OS X:
00045
00046 There are no dependences for OS X.
00047     ------------------------------------------------------------------
00048
00049 ## 3. Installation
00050
00051 ### PART 1. CONFIGURATION OF THE MAKEFILE.
```

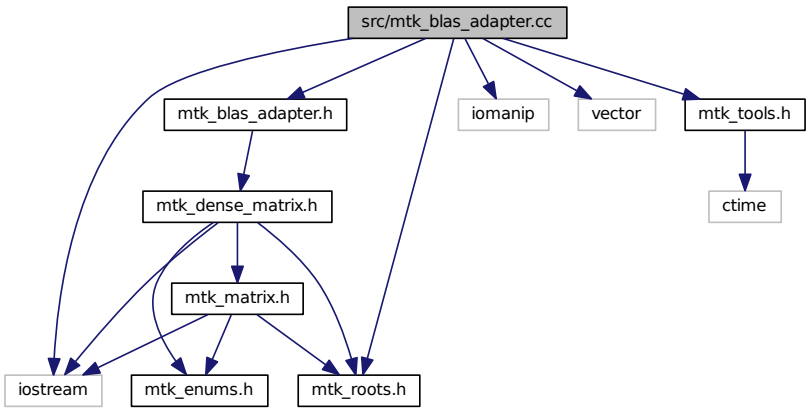
```
00052
00053 The following steps are required the build and test the MTK. Please use the
00054 accompanying `makefile_inc` file, which should provide a solid template to
00055 start with. The following command provides help on the options for make:
00056
00057 ```
00058 $ make help
00059 -----
00060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

```
00133
00134 Thanks and happy coding!
```

17.33 src/mtk_blas_adapter.cc File Reference

```
#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, Real *x, int *incx)
- void mtk::sgemv_ (char *trans, int *m, int *n, Real *alpha, Real *a, int *lda, Real *x, int *incx, Real *beta, Real *y, int *incy)
- void mtk::sgemm_ (char *transa, char *transb, int *m, int *n, int *k, Real *alpha, Real *a, int *lda, Real *b, aamm int *ldb, Real *beta, Real *c, int *ldc)

17.34 mtk_blas_adapter.cc

```
00001
00024 /*
00025 Copyright (C) 2015, Computational Science Research Center, San Diego State
00026 University. All rights reserved.
```

```
00027
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00029 are permitted provided that the following conditions are met:
00030
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00032 and a copy of the modified files should be reported once modifications are
00033 completed. Documentation related to said modifications should be included.
00034
00035 2. Redistributions of source code must be done through direct
00036 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00037
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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 #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
00095 double dnrm2_(int *n, Real *x, int *incx);
00096 #else
00097
00108 float snrm2_(int *n, Real *x, int *incx);
00109 #endif
00110
00111 #ifdef MTK_PRECISION_DOUBLE
00112
00140 void dgemv_(char *trans,
00141             int *m,
00142             int *n,
00143             Real *alpha,
00144             Real *a,
00145             int *lda,
00146             Real *x,
00147             int *incx,
00148             Real *beta,
00149             Real *y,
00150             int *incy);
00151 #else
00152
00180 void sgemv_(char *trans,
00181             int *m,
```

```
00182             int *n,
00183             Real *alpha,
00184             Real *a,
00185             int *lda,
00186             Real *x,
00187             int *incx,
00188             Real *beta,
00189             Real *y,
00190             int *incy);
00191 #endif
00192
00193 #ifdef MTK_PRECISION_DOUBLE
00194
00219 void dgemm_(char *transa,
00220             char* transb,
00221             int *m,
00222             int *n,
00223             int *k,
00224             Real *alpha,
00225             Real *a,
00226             int *lda,
00227             Real *b,
00228             int *ldb,
00229             Real *beta,
00230             Real *c,
00231             int *ldc);
00232 }
00233 #else
00234
00259 void sgemm_(char *transa,
00260             char* transb,
00261             int *m,
00262             int *n,
00263             int *k,
00264             Real *alpha,
00265             Real *a,
00266             int *lda,
00267             Real *b,aamm
00268             int *ldb,
00269             Real *beta,
00270             Real *c,
00271             int *ldc);
00272 }
00273 #endif
00274 }
00275
00276 mtk::Real mtk::BLASAdapter::RealNRM2(Real *in, int &in_length) {
00277
00278   int ix{1};  // Increment for the elements of xx. ix >= 0.
00279
00280   #ifdef MTK_PRECISION_DOUBLE
00281   return dnrm2_(&in_length, in, &ix);
00282   #else
00283   return snrm2_(&in_length, in, &ix);
00284   #endif
00285 }
00286
00287 void mtk::BLASAdapter::RealDenseMV(mtk::Real &alpha,
00288                                    mtk::DenseMatrix &aa,
00289                                    mtk::Real *xx,
00290                                    mtk::Real &beta,
00291                                    mtk::Real *yy) {
00292
00293   // Make sure input matrices are row-major ordered.
00294
00295   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00296     aa.OrderRowMajor();
00297   }
00298
00299   char transa{'T'}; // State that now, the input WILL be in row-major ordering.
00300
00301   int mm{aa.num_rows()};                  // Rows of aa.
00302   int nn{aa.num_cols()};                  // Columns of aa.
00303   int lda{(aa.matrix_properties()).ld()}; // Leading dimension.
00304   int incx{1};                            // Increment of values in x.
00305   int incy{1};                            // Increment of values in y.
00306
00307   std::swap(mm,nn);
00308   #ifdef MTK_PRECISION_DOUBLE
00309   dgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
```

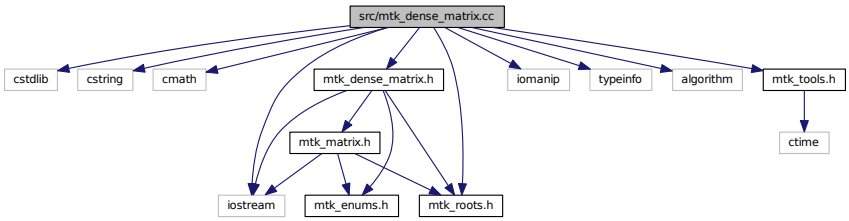
```
00310           xx, &incx, &beta, yy, &incy);
00311   #else
00312   sgemv_(&transa, &mm, &nn, &alpha, aa.data(), &lda,
00313         xx, &incx, &beta, yy, &incy);
00314   #endif
00315   std::swap(mm,nn);
00316 }
00317
00318 mtk::DenseMatrix mtk::BLASAdapter::RealDenseMM(
      mtk::DenseMatrix &aa,
00319                                                mtk::DenseMatrix &bb) {
00320
00321   #if MTK_DEBUG_LEVEL > 0
00322   mtk::Tools::Prevent(aa.num_cols() != bb.num_rows(),
00323                       __FILE__, __LINE__, __func__);
00324   #endif
00325
00326   // Make sure input matrices are row-major ordered.
00327
00328   if (aa.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00329     aa.OrderRowMajor();
00330   }
00331   if (bb.matrix_properties().ordering() ==
      mtk::COL_MAJOR) {
00332     bb.OrderRowMajor();
00333   }
00334
00335   char ta{'T'}; // State that input matrix aa is in row-wise ordering.
00336   char tb{'T'}; // State that input matrix bb is in row-wise ordering.
00337
00338   int mm{aa.num_rows()};  // Rows of aa and rows of cc.
00339   int nn{bb.num_cols()};  // Cols of bb and cols of cc.
00340   int kk{aa.num_cols()};  // Cols of aa and rows of bb.
00341
00342   int cc_num_rows{mm};  // Rows of cc.
00343   int cc_num_cols{nn};  // Columns of cc.
00344
00345   int lda{std::max(1,kk)};  // Leading dimension of the aa matrix.
00346   int ldb{std::max(1,nn)};  // Leading dimension of the bb matrix.
00347   int ldc{std::max(1,mm)};  // Leading dimension of the cc matrix.
00348
00349   mtk::Real alpha{1.0}; // First scalar coefficient.
00350   mtk::Real beta{0.0};  // Second scalar coefficient.
00351
00352   mtk::DenseMatrix cc_col_maj_ord(cc_num_rows,cc_num_cols); // Output matrix.
00353
00354   cc_col_maj_ord.SetOrdering(mtk::COL_MAJOR);
00355
00356   #ifdef MTK_PRECISION_DOUBLE
00357   dgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00358          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00359   #else
00360   sgemm_(&ta, &tb, &mm, &nn, &kk, &alpha, aa.data(), &lda,
00361          bb.data(), &ldb, &beta, cc_col_maj_ord.data(), &ldc);
00362   #endif
00363
00364   #if MTK_DEBUG_LEVEL > 0
00365   std::cout << "cc_col_maj_ord =" << std::endl;
00366   std::cout << cc_col_maj_ord << std::endl;
00367   #endif
00368
00369   cc_col_maj_ord.OrderRowMajor();
00370
00371   return cc_col_maj_ord;
00372 }
```

17.35 src/mtk_dense_matrix.cc File Reference

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

```
#include <cstdlib>
#include <cstring>
#include <cmath>
#include <iostream>
#include <iomanip>
#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)

17.35.1 Detailed Description

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

Author

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

Definition in file mtk_dense_matrix.cc.

17.36 mtk_dense_matrix.cc

```
00001
00013 /*
00014 Copyright (C) 2015, Computational Science Research Center, San Diego State
00015 University. All rights reserved.
00016
```

```
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00018 are permitted provided that the following conditions are met:
00019
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00021 and a copy of the modified files should be reported once modifications are
00022 completed. Documentation related to said modifications should be included.
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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00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */
00058
00059 #include <cstdlib>
00060 #include <cstring>
00061 #include <cmath>
00062
00063 #include <iostream>
00064 #include <iomanip>
00065 #include <typeinfo>
00066
00067 #include <algorithm>
00068
00069 #include "mtk_roots.h"
00070 #include "mtk_dense_matrix.h"
00071 #include "mtk_tools.h"
00072
00073 namespace mtk {
00074
00075 std::ostream& operator <<(std::ostream &stream, mtk::DenseMatrix &in) {
00076
00077   int mm{in.matrix_properties_.num_rows()};  // Auxiliary.
00078   int nn{in.matrix_properties_.num_cols()};  // Auxiliary.
00079
00080   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00081     std::swap(mm, nn);
00082   }
00083   for (auto ii = 0; ii < mm; ii++) {
00084     for (auto jj = 0; jj < nn; jj++) {
00085       mtk::Real value = in.data_[ii*nn + jj];
00086       stream << std::setw(13) << value;
00087     }
00088     stream << std::endl;
00089   }
00090   if (in.matrix_properties_.ordering() ==
      mtk::COL_MAJOR) {
00091     std::swap(mm, nn);
00092   }
00093   return stream;
00094 }
00095 }
```

```
00096
00097 mtk::DenseMatrix& mtk::DenseMatrix::operator =(const
      mtk::DenseMatrix &in) {
00098
00099   if(this == &in) {
00100     return *this;
00101   }
00102
00103   matrix_properties_.set_storage(in.
      matrix_properties_.storage());
00104
00105   matrix_properties_.set_ordering(in.
      matrix_properties_.ordering());
00106
00107   auto aux = in.matrix_properties_.num_rows();
00108   matrix_properties_.set_num_rows(aux);
00109
00110   aux = in.matrix_properties().num_cols();
00111   matrix_properties_.set_num_cols(aux);
00112
00113   aux = in.matrix_properties().num_zero();
00114   matrix_properties_.set_num_zero(aux);
00115
00116   aux = in.matrix_properties().num_null();
00117   matrix_properties_.set_num_null(aux);
00118
00119   auto num_rows = matrix_properties_.num_rows();
00120   auto num_cols = matrix_properties_.num_cols();
00121
00122   delete [] data_;
00123
00124   try {
00125     data_ = new mtk::Real[num_rows*num_cols];
00126   } catch (std::bad_alloc &memory_allocation_exception) {
00127     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00128       std::endl;
00129     std::cerr << memory_allocation_exception.what() << std::endl;
00130   }
00131   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*
      num_cols);
00132
00133   std::copy(in.data_, in.data_ + num_rows*num_cols, data_);
00134
00135   return *this;
00136 }
00137
00138 mtk::DenseMatrix::DenseMatrix(): data_(nullptr) {
00139
00140   matrix_properties_.set_storage(mtk::DENSE);
00141   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00142 }
00143
00144 mtk::DenseMatrix::DenseMatrix(const
      mtk::DenseMatrix &in) {
00145
00146   matrix_properties_.set_storage(in.matrix_properties_.storage());
00147
00148   matrix_properties_.set_ordering(in.matrix_properties_.
      ordering());
00149
00150   auto aux = in.matrix_properties_.num_rows();
00151   matrix_properties_.set_num_rows(aux);
00152
00153   aux = in.matrix_properties().num_cols();
00154   matrix_properties_.set_num_cols(aux);
00155
00156   aux = in.matrix_properties().num_zero();
00157   matrix_properties_.set_num_zero(aux);
00158
00159   aux = in.matrix_properties().num_null();
00160   matrix_properties_.set_num_null(aux);
00161
00162   auto num_rows = in.matrix_properties_.num_rows();
00163   auto num_cols = in.matrix_properties_.num_cols();
00164
00165   try {
00166     data_ = new mtk::Real[num_rows*num_cols];
00167   } catch (std::bad_alloc &memory_allocation_exception) {
00168     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00169       std::endl;
00170     std::cerr << memory_allocation_exception.what() << std::endl;
```

```
00171   }
00172   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00173
00174   std::copy(in.data_,in.data_ + num_rows*num_cols,data_);
00175 }
00176
00177 mtk::DenseMatrix::DenseMatrix(const int &num_rows, const int &num_cols) {
00178
00179   #if MTK_DEBUG_LEVEL > 0
00180   mtk::Tools::Prevent(num_rows < 1, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent(num_cols < 1, __FILE__, __LINE__, __func__);
00182   #endif
00183
00184   matrix_properties_.set_storage(mtk::DENSE);
00185   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00186   matrix_properties_.set_num_rows(num_rows);
00187   matrix_properties_.set_num_cols(num_cols);
00188
00189   try {
00190     data_ = new mtk::Real[num_rows*num_cols];
00191   } catch (std::bad_alloc &memory_allocation_exception) {
00192     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00193       std::endl;
00194     std::cerr << memory_allocation_exception.what() << std::endl;
00195   }
00196   memset(data_, mtk::kZero, sizeof(data_[0])*num_rows*num_cols);
00197 }
00198
00199 mtk::DenseMatrix::DenseMatrix(const int &rank,
00200                               const bool &padded,
00201                               const bool &transpose) {
00202
00203   #if MTK_DEBUG_LEVEL > 0
00204   mtk::Tools::Prevent(rank < 1, __FILE__, __LINE__, __func__);
00205   #endif
00206
00207   int aux{};  // Used to control the padding.
00208
00209   if (padded) {
00210     aux = 1;
00211   }
00212
00213   matrix_properties_.set_storage(mtk::DENSE);
00214   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00215   matrix_properties_.set_num_rows(aux + rank + aux);
00216   matrix_properties_.set_num_cols(rank);
00217
00218   try {
00219     data_ = new mtk::Real[matrix_properties_.num_values()];
00220   } catch (std::bad_alloc &memory_allocation_exception) {
00221     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00222       std::endl;
00223     std::cerr << memory_allocation_exception.what() << std::endl;
00224   }
00225   memset(data_,
00226          mtk::kZero,
00227          sizeof(data_[0])*(matrix_properties_.num_values()));
00228
00229   for (auto ii =0 ; ii < matrix_properties_.num_rows(); ++ii) {
00230     for (auto jj = 0; jj < matrix_properties_.num_cols(); ++jj) {
00231       data_[ii*matrix_properties_.num_cols() + jj] =
00232         (ii == jj + aux)? mtk::kOne: mtk::kZero;
00233     }
00234   }
00235 }
00236
00237 mtk::DenseMatrix::DenseMatrix(const mtk::Real *gen,
00238                               const int &gen_length,
00239                               const int &pro_length,
00240                               const bool &transpose) {
00241
00242   #if MTK_DEBUG_LEVEL > 0
00243   mtk::Tools::Prevent(gen == nullptr, __FILE__, __LINE__, __func__);
00244   mtk::Tools::Prevent(gen_length < 1, __FILE__, __LINE__, __func__);
00245   mtk::Tools::Prevent(pro_length < 1, __FILE__, __LINE__, __func__);
00246   #endif
00247
00248   matrix_properties_.set_storage(mtk::DENSE);
00249   matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00250   if (!transpose) {
00251     matrix_properties_.set_num_rows(gen_length);
```

```
00252     matrix_properties_.set_num_cols(pro_length);
00253   } else {
00254     matrix_properties_.set_num_rows(pro_length);
00255     matrix_properties_.set_num_cols(gen_length);
00256   }
00257
00258   int rr = matrix_properties_.num_rows(); // Used to construct this matrix.
00259   int cc = matrix_properties_.num_cols(); // Used to construct this matrix.
00260
00261   try {
00262     data_ = new mtk::Real[rr*cc];
00263   } catch (std::bad_alloc &memory_allocation_exception) {
00264     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00265       std::endl;
00266     std::cerr << memory_allocation_exception.what() << std::endl;
00267   }
00268   memset(data_, mtk::kZero, sizeof(data_[0])*rr*cc);
00269
00270   if (!transpose) {
00271     for (auto ii = 0; ii < rr; ii++) {
00272       for (auto jj = 0; jj < cc; jj++) {
00273         data_[ii*cc + jj] = pow(gen[ii], (double) jj);
00274       }
00275     }
00276   } else {
00277     for (auto ii = 0; ii < rr; ii++) {
00278       for (auto jj = 0; jj < cc; jj++) {
00279         data_[ii*cc + jj] = pow(gen[jj], (double) ii);
00280       }
00281     }
00282   }
00283 }
00284
00285 mtk::DenseMatrix::~DenseMatrix() {
00286
00287   delete[] data_;
00288   data_ = nullptr;
00289 }
00290
00291 mtk::Matrix mtk::DenseMatrix::matrix_properties() const {
00292
00293   return matrix_properties_;
00294 }
00295
00296 void mtk::DenseMatrix::SetOrdering(
      mtk::MatrixOrdering oo) {
00297
00298   #if MTK_DEBUG_LEVEL > 0
00299   mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
      mtk::COL_MAJOR),
00300                       __FILE__, __LINE__, __func__);
00301   #endif
00302
00303   matrix_properties_.set_ordering(oo);
00304 }
00305
00306 int mtk::DenseMatrix::num_rows() const {
00307
00308   return matrix_properties_.num_rows();
00309 }
00310
00311 int mtk::DenseMatrix::num_cols() const {
00312
00313   return matrix_properties_.num_cols();
00314 }
00315
00316 mtk::Real* mtk::DenseMatrix::data() const {
00317
00318   return data_;
00319 }
00320
00321 mtk::Real mtk::DenseMatrix::GetValue(
00322     const int &rr,
00323     const int &cc) const {
00324
00325   #if MTK_DEBUG_LEVEL > 0
00326   mtk::Tools::Prevent(rr < 0, __FILE__, __LINE__, __func__);
00327   mtk::Tools::Prevent(cc < 0, __FILE__, __LINE__, __func__);
00328   #endif
00329
00330   return data_[rr*matrix_properties_.num_cols() + cc];
```

```
00331 }
00332
00333 void  mtk::DenseMatrix::SetValue(
00334     const int &rr,
00335     const int &cc,
00336     const mtk::Real &val) {
00337
00338   #if MTK_DEBUG_LEVEL > 0
00339   mtk::Tools::Prevent(rr < 0, __FILE__, __LINE__, __func__);
00340   mtk::Tools::Prevent(cc < 0, __FILE__, __LINE__, __func__);
00341   #endif
00342
00343   data_[rr*matrix_properties_.num_cols() + cc] = val;
00344 }
00345
00346 void mtk::DenseMatrix::Transpose() {
00347
00349
00350   mtk::Real *data_transposed{}; // Buffer.
00351
00352   int rr = matrix_properties_.num_rows(); // Used to construct this matrix.
00353   int cc = matrix_properties_.num_cols(); // Used to construct this matrix.
00354
00355   try {
00356     data_transposed = new mtk::Real[rr*cc];
00357   } catch (std::bad_alloc &memory_allocation_exception) {
00358     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00359       std::endl;
00360     std::cerr << memory_allocation_exception.what() << std::endl;
00361   }
00362   memset(data_transposed,
00363          mtk::kZero,
00364          sizeof(data_transposed[0])*rr*cc);
00365
00366   // Assign the values to their transposed position.
00367   for (auto ii = 0; ii < rr; ++ii) {
00368     for (auto jj = 0; jj < cc; ++jj) {
00369       data_transposed[jj*rr + ii] = data_[ii*cc + jj];
00370     }
00371   }
00372
00373   // Swap pointers.
00374   auto tmp = data_; // Temporal holder.
00375   data_ = data_transposed;
00376   delete [] tmp;
00377   tmp = nullptr;
00378
00379   matrix_properties_.set_num_rows(cc);
00380   matrix_properties_.set_num_cols(rr);
00381 }
00382
00383 void mtk::DenseMatrix::OrderRowMajor() {
00384
00385   if (matrix_properties_.ordering() == mtk::COL_MAJOR) {
00386
00388
00389     mtk::Real *data_transposed{}; // Buffer.
00390
00391     int rr = matrix_properties_.num_rows(); // Used to construct this matrix.
00392     int cc = matrix_properties_.num_cols(); // Used to construct this matrix.
00393
00394     try {
00395       data_transposed = new mtk::Real[rr*cc];
00396     } catch (std::bad_alloc &memory_allocation_exception) {
00397       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00398         std::endl;
00399       std::cerr << memory_allocation_exception.what() << std::endl;
00400     }
00401     memset(data_transposed,
00402            mtk::kZero,
00403            sizeof(data_transposed[0])*rr*cc);
00404
00405     // Assign the values to their transposed position.
00406     std::swap(rr, cc);
00407     for (auto ii = 0; ii < rr; ++ii) {
00408       for (auto jj = 0; jj < cc; ++jj) {
00409         data_transposed[jj*rr + ii] = data_[ii*cc + jj];
00410       }
00411     }
00412     std::swap(rr, cc);
00413
```

```
00414     // Swap pointers.
00415     auto tmp = data_; // Temporal holder.
00416     data_ = data_transposed;
00417     delete [] tmp;
00418     tmp = nullptr;
00419
00420     matrix_properties_.set_ordering(mtk::ROW_MAJOR);
00421   }
00422 }
00423
00424 void mtk::DenseMatrix::OrderColMajor() {
00425
00426   if (matrix_properties_.ordering() == ROW_MAJOR) {
00427
00428
00429
00430     mtk::Real *data_transposed{}; // Buffer.
00431
00432     int rr = matrix_properties_.num_rows(); // Used to construct this matrix.
00433     int cc = matrix_properties_.num_cols(); // Used to construct this matrix.
00434
00435     try {
00436       data_transposed = new mtk::Real[rr*cc];
00437     } catch (std::bad_alloc &memory_allocation_exception) {
00438       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00439         std::endl;
00440       std::cerr << memory_allocation_exception.what() << std::endl;
00441     }
00442     memset(data_transposed,
00443           mtk::kZero,
00444           sizeof(data_transposed[0])*rr*cc);
00445
00446     // Assign the values to their transposed position.
00447     for (auto ii = 0; ii < rr; ++ii) {
00448       for (auto jj = 0; jj < cc; ++jj) {
00449         data_transposed[jj*rr + ii] = data_[ii*cc + jj];
00450       }
00451     }
00452
00453     // Swap pointers.
00454     auto tmp = data_; // Temporal holder.
00455     data_ = data_transposed;
00456     delete [] tmp;
00457     tmp = nullptr;
00458
00459     matrix_properties_.set_ordering(mtk::COL_MAJOR);
00460   }
00461 }
00462
00463 mtk::DenseMatrix mtk::DenseMatrix::Kron(const
      mtk::DenseMatrix &aa,
00464                                         const mtk::DenseMatrix &bb) {
00465
00466   register double aa_factor{};  // Used in computation.
00467   register int row_offset{};    // Offset for rows.
00468   register int col_offset{};    // Offset for rows.
00469
00470   // Auxiliary variables:
00471   auto aux1 = aa.matrix_properties_.num_rows()*bb.
      matrix_properties_.num_rows();
00472   auto aux2 = aa.matrix_properties_.num_cols()*bb.
      matrix_properties_.num_cols();
00473
00474   mtk::DenseMatrix output(aux1,aux2); // Output matrix.
00475
00476   register int kk_num_cols{output.matrix_properties_.num_cols()}; // Aux.
00477
00478   auto mm = aa.matrix_properties_.num_rows(); // Rows of aa.
00479   auto nn = aa.matrix_properties_.num_cols(); // Cols of aa.
00480   auto pp = bb.matrix_properties_.num_rows(); // Rows of bb.
00481   auto qq = bb.matrix_properties_.num_cols(); // Cols of bb.
00482
00483   for (auto ii = 0; ii < mm; ++ii) {
00484     row_offset = ii*pp;
00485     for (auto jj = 0; jj < nn; ++jj) {
00486       col_offset = jj*qq;
00487       aa_factor = aa.data_[ii*nn + jj];
00488       for (auto ll = 0; ll < pp; ++ll) {
00489         for (auto oo = 0; oo < qq; ++oo) {
00490           auto index = (ll + row_offset)*kk_num_cols + (oo + col_offset);
00491           output.data_[index] = aa_factor*bb.data_[ll*qq + oo];
00492         }
```

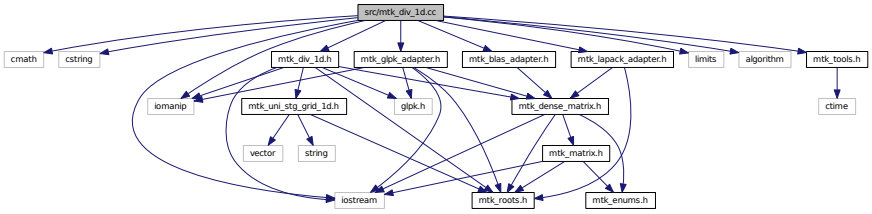
```
00493       }
00494     }
00495   }
00496
00497   output.matrix_properties_.set_storage(mtk::DENSE);
00498   output.matrix_properties_.set_ordering(
      mtk::ROW_MAJOR);
00499
00500   return output;
00501 }
```

17.37 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)

17.37.1 Detailed Description

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

Author

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

Todo Overload ostream operator as in mtk::Lap1D.

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

Definition in file mtk_div_1d.cc.

17.38 mtk_div_1d.cc

```
00001
00015 /*
00016 Copyright (C) 2015, Computational Science Research Center, San Diego State
00017 University. All rights reserved.
00018
00019 Redistribution and use in source and binary forms, with or without modification,
00020 are permitted provided that the following conditions are met:
00021
00022 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00023 and a copy of the modified files should be reported once modifications are
00024 completed. Documentation related to said modifications should be included.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions of source code must retain the above copyright notice, this
00030 list of conditions and the following disclaimer.
00031
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00034 other materials provided with the distribution.
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00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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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
00097
00098     stream << "divergence_[" << in.order_accuracy_ + 1 << ":" <<
00099       2*in.order_accuracy_ << "] = ";
00100     for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00101       stream << std::setw(9) << in.divergence_[ii] << " ";
00102     }
00103     stream << std::endl;
00104
00106
00107     auto offset = (2*in.order_accuracy_ + 1);
00108     int mm{};
00109     for (auto ii = 0; ii < in.dim_null_; ++ii) {
00110       stream << "divergence_[" << offset + mm << ":" <<
00111         offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; ++jj) {
00113         auto value = in.divergence_[offset + mm];
00114         stream << std::setw(9) << value << " ";
00115         ++mm;
00116       }
00117       stream << std::endl;
00118     }
00119   }
00120
00121   return stream;
00122 }
00123 }
00124
00125 mtk::Div1D::Div1D():
00126   order_accuracy_(mtk::kDefaultOrderAccuracy),
00127   dim_null_(),
00128   num_bndy_coeffs_(),
00129   divergence_length_(),
00130   minrow_(),
00131   row_(),
00132   coeffs_interior_(),
00133   prem_apps_(),
00134   weights_crs_(),
00135   weights_cbs_(),
00136   mim_bndy_(),
00137   divergence_(),
00138   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00139
00140 mtk::Div1D::Div1D(const Div1D &div):
00141   order_accuracy_(div.order_accuracy_),
00142   dim_null_(div.dim_null_),
00143   num_bndy_coeffs_(div.num_bndy_coeffs_),
00144   divergence_length_(div.divergence_length_),
00145   minrow_(div.minrow_),
00146   row_(div.row_),
00147   coeffs_interior_(div.coeffs_interior_),
00148   prem_apps_(div.prem_apps_),
00149   weights_crs_(div.weights_crs_),
00150   weights_cbs_(div.weights_cbs_),
00151   mim_bndy_(div.mim_bndy_),
00152   divergence_(div.divergence_),
00153   mimetic_threshold_(div.mimetic_threshold_) {}
00154
00155 mtk::Div1D::~Div1D() {
00156
00157   delete[] coeffs_interior_;
00158   coeffs_interior_ = nullptr;
```

```
00159
00160   delete[] prem_apps_;
00161   prem_apps_ = nullptr;
00162
00163   delete[] weights_crs_;
00164   weights_crs_ = nullptr;
00165
00166   delete[] weights_cbs_;
00167   weights_cbs_ = nullptr;
00168
00169   delete[] mim_bndy_;
00170   mim_bndy_ = nullptr;
00171
00172   delete[] divergence_;
00173   divergence_ = nullptr;
00174 }
00175
00176 bool mtk::Div1D::ConstructDiv1D(int order_accuracy,
00177                                 mtk::Real mimetic_threshold) {
00178
00179   #if MTK_DEBUG_LEVEL > 0
00180   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00181   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00182   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00183                       __FILE__, __LINE__, __func__);
00184
00185   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00186     std::cout << "WARNING: Numerical accuracy is critical." << std::endl;
00187   }
00188
00189   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00190   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00191   #endif
00192
00193   order_accuracy_ = order_accuracy;
00194   mimetic_threshold_ = mimetic_threshold;
00195
00197
00198   bool abort_construction = ComputeStencilInteriorGrid();
00199
00200   #if MTK_DEBUG_LEVEL > 0
00201   if (!abort_construction) {
00202     std::cerr << "Could NOT complete stage 1." << std::endl;
00203     std::cerr << "Exiting..." << std::endl;
00204     return false;
00205   }
00206   #endif
00207
00208   // At this point, we already have the values for the interior stencil stored
00209   // in the coeffs_interior_ array.
00210
00211   // It is noteworthy, that the 2nd-order-accurate divergence operator has NO
00212   // approximation at the boundary, thus it has no weights. For this case, the
00213   // dimension of the null-space of the Vandermonde matrices used to compute the
00214   // approximating coefficients at the boundary is 0. Ergo, we compute this
00215   // number first and then decide if we must compute anything at the boundary.
00216
00217   dim_null_ = order_accuracy_/2 - 1;
00218
00219   if (dim_null_ > 0) {
00220
00221     #ifdef MTK_PRECISION_DOUBLE
00222     num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00223     #else
00224     num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00225     #endif
00226
00228
00229     // For this we will follow recommendations given in:
00230     //
00231     // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00232     //
00233     // We will compute the QR Factorization of the transpose, as in the
00234     // following (MATLAB) pseudo-code:
00235     //
00236     // [Q,R] = qr(V'); % Full QR as defined in
00237     // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00238     //
00239     // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00240     //
00241     // However, given the nature of the Vandermonde matrices we've just
```

```
00242     // computed, they all posses the same null-space. Therefore, we impose the
00243     // convention of computing the null-space of the first Vandermonde matrix
00244     // (west boundary).
00245
00246     abort_construction = ComputeRationalBasisNullSpace();
00247
00248     #if MTK_DEBUG_LEVEL > 0
00249     if (!abort_construction) {
00250       std::cerr << "Could NOT complete stage 2.1." << std::endl;
00251       std::cerr << "Exiting..." << std::endl;
00252       return false;
00253     }
00254     #endif
00255
00257
00258     abort_construction = ComputePreliminaryApproximations();
00259
00260     #if MTK_DEBUG_LEVEL > 0
00261     if (!abort_construction) {
00262       std::cerr << "Could NOT complete stage 2.2." << std::endl;
00263       std::cerr << "Exiting..." << std::endl;
00264       return false;
00265     }
00266     #endif
00267
00269
00270     abort_construction = ComputeWeights();
00271
00272     #if MTK_DEBUG_LEVEL > 0
00273     if (!abort_construction) {
00274       std::cerr << "Could NOT complete stage 2.3." << std::endl;
00275       std::cerr << "Exiting..." << std::endl;
00276       return false;
00277     }
00278     #endif
00279
00281
00282     abort_construction = ComputeStencilBoundaryGrid();
00283
00284     #if MTK_DEBUG_LEVEL > 0
00285     if (!abort_construction) {
00286       std::cerr << "Could NOT complete stage 2.4." << std::endl;
00287       std::cerr << "Exiting..." << std::endl;
00288       return false;
00289     }
00290     #endif
00291
00292   } // End of: if (dim_null_ > 0);
00293
00295
00296   // Once we have the following three collections of data:
00297   //   (a) the coefficients for the interior,
00298   //   (b) the coefficients for the boundary (if it applies),
00299   //   (c) and the weights (if it applies),
00300   // we will store everything in the output array:
00301
00302   abort_construction = AssembleOperator();
00303
00304   #if MTK_DEBUG_LEVEL > 0
00305   if (!abort_construction) {
00306     std::cerr << "Could NOT complete stage 3." << std::endl;
00307     std::cerr << "Exiting..." << std::endl;
00308     return false;
00309   }
00310   #endif
00311
00312   return true;
00313 }
00314
00315 mtk::Real *mtk::Div1D::weights_crs() {
00316
00317   return weights_crs_;
00318 }
00319
00320 mtk::Real *mtk::Div1D::weights_cbs() {
00321
00322   return weights_cbs_;
00323 }
00324
00325 mtk::DenseMatrix mtk::Div1D::ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) {
```

```
00326
00327   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00328
00329   #if MTK_DEBUG_LEVEL > 0
00330   mtk::Tools::Prevent(order_accuracy_ <= 0, __FILE__, __LINE__, __func__);
00331   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00332   #endif
00333
00334   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00335
00336   int dd_num_rows = nn + 2;
00337   int dd_num_cols = nn + 1;
00338   int elements_per_row = num_bndy_coeffs_;
00339   int num_extra_rows = dim_null_;
00340
00341   // Output matrix featuring sizes for divergence operators.
00342   mtk::DenseMatrix out(dd_num_rows, dd_num_cols);
00343
00345
00346   auto ee_index = 0;
00347   for (auto ii = 1; ii < num_extra_rows + 1; ii++) {
00348     auto cc = 0;
00349     for(auto jj = 0 ; jj < dd_num_rows; jj++) {
00350       if( cc >= elements_per_row) {
00351         out.SetValue(ii, jj, mtk::kZero);
00352       } else {
00353         out.SetValue(ii,jj, mim_bndy_[ee_index++]*inv_delta_x);
00354         cc++;
00355       }
00356     }
00357   }
00358
00360
00361   for (auto ii = num_extra_rows + 1;
00362        ii < dd_num_rows - num_extra_rows - 1; ii++) {
00363     auto jj = ii - num_extra_rows - 1;
00364     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00365       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00366     }
00367   }
00368
00370
00371   ee_index = 0;
00372   for (auto ii = dd_num_rows - 2; ii >= dd_num_rows - num_extra_rows - 1; ii--) {
00373     auto cc = 0;
00374     for (auto jj = dd_num_cols - 1; jj >= 0; jj--) {
00375       if( cc >= elements_per_row) {
00376         out.SetValue(ii,jj,0.0);
00377       } else {
00378         out.SetValue(ii,jj,-mim_bndy_[ee_index++]*inv_delta_x);
00379         cc++;
00380       }
00381      }
00382   }
00383
00384   return out;
00385 }
00386
00387 bool mtk::Div1D::ComputeStencilInteriorGrid() {
00388
00390
00391   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00392
00393   try {
00394     pp = new mtk::Real[order_accuracy_];
00395   } catch (std::bad_alloc &memory_allocation_exception) {
00396     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00397       std::endl;
00398     std::cerr << memory_allocation_exception.what() << std::endl;
00399   }
00400   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00401
00402   #ifdef MTK_PRECISION_DOUBLE
00403   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00404   #else
00405   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00406   #endif
00407
00408   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00409     pp[ii] = pp[ii - 1] + mtk::kOne;
00410   }
```

```
00411
00412   #if MTK_DEBUG_LEVEL > 0
00413   std::cout << "pp =" << std::endl;
00414   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00415     std::cout << std::setw(12) << pp[ii];
00416   }
00417   std::cout << std::endl << std::endl;
00418   #endif
00419
00421
00422   bool transpose{false};
00423
00424   mtk::DenseMatrix vander_matrix(pp,
00425                                  order_accuracy_,
00426                                  order_accuracy_,
00427                                  transpose);
00428
00429   #if MTK_DEBUG_LEVEL > 0
00430   std::cout << "vander_matrix = " << std::endl;
00431   std::cout << vander_matrix << std::endl;
00432   #endif
00433
00435
00436   try {
00437     coeffs_interior_ = new mtk::Real[order_accuracy_];
00438   } catch (std::bad_alloc &memory_allocation_exception) {
00439     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00440       std::endl;
00441     std::cerr << memory_allocation_exception.what() << std::endl;
00442   }
00443   memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00444
00445   coeffs_interior_[1] = mtk::kOne;
00446
00447   #if MTK_DEBUG_LEVEL > 0
00448   std::cout << "oo =" << std::endl;
00449   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00450     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00451   }
00452   std::cout << std::endl;
00453   #endif
00454
00456
00457   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00458                                                 coeffs_interior_)};
00459
00460   #if MTK_DEBUG_LEVEL > 0
00461   if (!info) {
00462     std::cout << "System solved! Interior stencil attained!" << std::endl;
00463     std::cout << std::endl;
00464   }
00465   else {
00466     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00467     std::cerr << "Exiting..." << std::endl;
00468     return false;
00469   }
00470   #endif
00471
00472   #if MTK_DEBUG_LEVEL > 0
00473   std::cout << "coeffs_interior_ =" << std::endl;
00474   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00475     std::cout << std::setw(12) << coeffs_interior_[ii];
00476   }
00477   std::cout << std::endl << std::endl;
00478   #endif
00479
00480   delete [] pp;
00481   pp = nullptr;
00482
00483   return true;
00484 }
00485
00486 bool mtk::Div1D::ComputeRationalBasisNullSpace(void) {
00487
00488   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00489
00491
00492   try {
00493     gg = new mtk::Real[num_bndy_coeffs_];
00494   } catch (std::bad_alloc &memory_allocation_exception) {
00495     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
```

```
00496       std::endl;
00497     std::cerr << memory_allocation_exception.what() << std::endl;
00498   }
00499   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00500
00501   #ifdef MTK_PRECISION_DOUBLE
00502   gg[0] = -1.0/2.0;
00503   #else
00504   gg[0] = -1.0f/2.0f;
00505   #endif
00506   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00507     gg[ii] = gg[ii - 1] + mtk::kOne;
00508   }
00509
00510   #if MTK_DEBUG_LEVEL > 0
00511   std::cout << "gg =" << std::endl;
00512   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00513     std::cout << std::setw(12) << gg[ii];
00514   }
00515   std::cout << std::endl << std::endl;
00516   #endif
00517
00519
00520   bool tran{true}; // Should I transpose the Vandermonde matrix.
00521
00522   mtk::DenseMatrix vv_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
00523
00524   #if MTK_DEBUG_LEVEL > 0
00525   std::cout << "vv_west_t =" << std::endl;
00526   std::cout << vv_west_t << std::endl;
00527   #endif
00528
00530
00531   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (vv_west_t));
00532
00533   #if MTK_DEBUG_LEVEL > 0
00534   std::cout << "QQ^T = " << std::endl;
00535   std::cout << qq_t << std::endl;
00536   #endif
00537
00539
00540   int KK_num_rows_{num_bndy_coeffs_};
00541   int KK_num_cols_{dim_null_};
00542
00543   mtk::DenseMatrix KK(KK_num_rows_, KK_num_cols_);
00544
00545   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00546     for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
00547       KK.data()[jj*dim_null_ + (ii - (num_bndy_coeffs_ - dim_null_))] =
00548           qq_t.data()[ii*num_bndy_coeffs_ + jj];
00549     }
00550   }
00551
00552   #if MTK_DEBUG_LEVEL > 0
00553   std::cout << "KK =" << std::endl;
00554   std::cout << KK << std::endl;
00555   std::cout << "KK.num_rows() = " << KK.num_rows() << std::endl;
00556   std::cout << "KK.num_cols() = " << KK.num_cols() << std::endl;
00557   std::cout << std::endl;
00558   #endif
00559
00561
00562   // Scale thus requesting that the last entries of the attained basis for the
00563   // null-space, adopt the pattern we require.
00564   // Essentially we will implement the following MATLAB pseudo-code:
00565   //  scalers = KK(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00566   //  SK = KK*scalers
00567   // where SK is the scaled null-space.
00568
00569   // In this point, we almost have all the data we need correctly allocated
00570   // in memory. We will create the matrix II_, and elements we wish to scale in
00571   // the KK array. Using the concept of the leading dimension, we could just
00572   // use KK, with the correct leading dimension and that is it. BUT I DO NOT
00573   // GET how does it work. So I will just create a matrix with the content of
00574   // this array that we need, solve for the scalers and then scale the
00575   // whole KK:
00576
00577   // We will then create memory for that sub-matrix of KK (SUBK).
00578
00579   mtk::DenseMatrix SUBK(dim_null_,dim_null_);
```

```
00580
00581   for (auto ii = num_bndy_coeffs_ - dim_null_; ii < num_bndy_coeffs_; ++ii) {
00582     for (auto jj = 0; jj < dim_null_; ++jj) {
00583       SUBK.data()[(ii - (num_bndy_coeffs_ - dim_null_))*dim_null_ + jj] =
00584           KK.data()[ii*dim_null_ + jj];
00585     }
00586   }
00587
00588   #if MTK_DEBUG_LEVEL > 0
00589   std::cout << "SUBK =" << std::endl;
00590   std::cout << SUBK << std::endl;
00591   #endif
00592
00593   SUBK.Transpose();
00594
00595   #if MTK_DEBUG_LEVEL > 0
00596   std::cout << "SUBK^T =" << std::endl;
00597   std::cout << SUBK << std::endl;
00598   #endif
00599
00600   bool padded{false};
00601   tran = false;
00602
00603   mtk::DenseMatrix II(dim_null_, padded, tran);
00604
00605   #if MTK_DEBUG_LEVEL > 0
00606   std::cout << "II =" << std::endl;
00607   std::cout << II << std::endl;
00608   #endif
00609
00610   // Solve the system to compute the scalers.
00611   // An example of the system to solve, for k = 8, is:
00612   //
00613   // SUBK*scalers = II_ or
00614   //
00615   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00616   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00617   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00618   //
00619   // Notice this is a nrhs = 3 system.
00620   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00621   // will be stored in the created identity matrix.
00622   // Let us first transpose SUBK (because of LAPACK):
00623
00624   int info{mtk::LAPACKAdapter::SolveDenseSystem(SUBK, II)};
00625
00626   #if MTK_DEBUG_LEVEL > 0
00627   if (!info) {
00628     std::cout << "System successfully solved!" <<
00629       std::endl;
00630   } else {
00631     std::cerr << "Something went wrong solving system! info = " << info <<
00632       std::endl;
00633     std::cerr << "Exiting..." << std::endl;
00634     return false;
00635   }
00636   std::cout << std::endl;
00637   #endif
00638
00639   #if MTK_DEBUG_LEVEL > 0
00640   std::cout << "Computed scalers:" << std::endl;
00641   std::cout << II << std::endl;
00642   #endif
00643
00644   // Multiply the two matrices to attain a scaled basis for null-space.
00645
00646   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(KK, II);
00647
00648   #if MTK_DEBUG_LEVEL > 0
00649   std::cout << "Rational basis for the null-space:" << std::endl;
00650   std::cout << rat_basis_null_space_ << std::endl;
00651   #endif
00652
00653   // At this point, we have a rational basis for the null-space, with the
00654   // pattern we need! :)
00655
00656   delete [] gg;
00657   gg = nullptr;
00658
00659   return true;
00660 }
```

```
00661
00662 bool mtk::Div1D::ComputePreliminaryApproximations(void) {
00663
00665
00666   mtk::Real *gg{}; // Generator vector for the first approximation.
00667
00668   try {
00669     gg = new mtk::Real[num_bndy_coeffs_];
00670   } catch (std::bad_alloc &memory_allocation_exception) {
00671     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00672 std::endl;
00673     std::cerr << memory_allocation_exception.what() << std::endl;
00674   }
00675   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00676
00677   #ifdef MTK_PRECISION_DOUBLE
00678   gg[0] = -1.0/2.0;
00679   #else
00680   gg[0] = -1.0f/2.0f;
00681   #endif
00682   for (auto ii = 1; ii < num_bndy_coeffs_; ++ii) {
00683     gg[ii] = gg[ii - 1] + mtk::kOne;
00684   }
00685
00686   #if MTK_DEBUG_LEVEL > 0
00687   std::cout << "gg0 =" << std::endl;
00688   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00689     std::cout << std::setw(12) << gg[ii];
00690   }
00691   std::cout << std::endl << std::endl;
00692   #endif
00693
00694   // Allocate 2D array to store the collection of preliminary approximations.
00695   try {
00696     prem_apps_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
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(prem_apps_,
00703          mtk::kZero,
00704          sizeof(prem_apps_[0])*num_bndy_coeffs_*dim_null_);
00705
00707
00708   for (auto ll = 0; ll < dim_null_; ++ll) {
00709
00710     // Re-check new generator vector for every iteration except for the first.
00711     #if MTK_DEBUG_LEVEL > 0
00712     if (ll > 0) {
00713       std::cout << "gg" << ll << " =" << std::endl;
00714       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00715         std::cout << std::setw(12) << gg[ii];
00716       }
00717       std::cout << std::endl << std::endl;
00718     }
00719     #endif
00720
00722
00723     bool transpose{false};
00724
00725     mtk::DenseMatrix AA_(gg,
00726                          num_bndy_coeffs_, order_accuracy_ + 1,
00727                          transpose);
00728
00729     #if MTK_DEBUG_LEVEL > 0
00730     std::cout << "AA_" << ll << " =" << std::endl;
00731     std::cout << AA_ << std::endl;
00732     #endif
00733
00735
00736     mtk::Real *ob{};
00737
00738     auto ob_ld = num_bndy_coeffs_;
00739
00740     try {
00741       ob = new mtk::Real[ob_ld];
00742     } catch (std::bad_alloc &memory_allocation_exception) {
00743       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00744         std::endl;
00745       std::cerr << memory_allocation_exception.what() << std::endl;
```

```
00746     }
00747     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00748
00749     ob[1] = mtk::kOne;
00750
00751     #if MTK_DEBUG_LEVEL > 0
00752     std::cout << "ob = " << std::endl << std::endl;
00753     for (auto ii = 0; ii < ob_ld; ++ii) {
00754       std::cout << std::setw(12) << ob[ii] << std::endl;
00755     }
00756     std::cout << std::endl;
00757     #endif
00758
00760
00761     // However, this is an under-determined system of equations. So we can not
00762     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00763     // our LAPACKAdapter class.
00764
00765     int info_{
00766       mtk::LAPACKAdapter::SolveRectangularDenseSystem(AA_,
      ob, ob_ld)};
00767
00768     #if MTK_DEBUG_LEVEL > 0
00769     if (!info_) {
00770       std::cout << "System successfully solved!" << std::endl << std::endl;
00771     } else {
00772       std::cerr << "Error solving system! info = " << info_ << std::endl;
00773     }
00774     #endif
00775
00776     #if MTK_DEBUG_LEVEL > 0
00777     std::cout << "ob =" << std::endl;
00778     for (auto ii = 0; ii < ob_ld; ++ii) {
00779       std::cout << std::setw(12) << ob[ii] << std::endl;
00780     }
00781     std::cout << std::endl;
00782     #endif
00783
00785
00786     // This implies a DAXPY operation. However, we must construct the arguments
00787     // for this operation.
00788
00790     // Save them into the ob_bottom array:
00791
00792     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00793
00794     try {
00795       ob_bottom = new mtk::Real[dim_null_];
00796     } catch (std::bad_alloc &memory_allocation_exception) {
00797       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00798         std::endl;
00799       std::cerr << memory_allocation_exception.what() << std::endl;
00800     }
00801     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00802
00803     for (auto ii = 0; ii < dim_null_; ++ii) {
00804       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00805     }
00806
00807     #if MTK_DEBUG_LEVEL > 0
00808     std::cout << "ob_bottom =" << std::endl;
00809     for (auto ii = 0; ii < dim_null_; ++ii) {
00810       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00811     }
00812     std::cout << std::endl;
00813     #endif
00814
00816
00817     // We must computed an scaled ob, sob, using the scaled null-space in
00818     // rat_basis_null_space_.
00819     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00820     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00821     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00822
00823     #if MTK_DEBUG_LEVEL > 0
00824     std::cout << "Rational basis for the null-space:" << std::endl;
00825     std::cout << rat_basis_null_space_ << std::endl;
00826     #endif
00827
00828     mtk::Real alpha{-mtk::kOne};
00829     mtk::Real beta{mtk::kOne};
```

```
00830
00831     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00832                                   ob_bottom, beta, ob);
00833
00834     #if MTK_DEBUG_LEVEL > 0
00835     std::cout << "scaled ob:" << std::endl;
00836     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00837       std::cout << std::setw(12) << ob[ii] << std::endl;
00838     }
00839     std::cout << std::endl;
00840     #endif
00841
00842     // We save the recently scaled solution, into an array containing these.
00843     // We can NOT start building the pi matrix, simply because I want that part
00844     // to be separated since its construction depends on the algorithm we want
00845     // to implement.
00846
00847     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00848       prem_apps_[ii*dim_null_ + ll] = ob[ii];
00849     }
00850
00851     // After the first iteration, simply shift the entries of the last
00852     // generator vector used:
00853     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00854       gg[ii]--;
00855     }
00856
00857     // Garbage collection for this loop:
00858     delete[] ob;
00859     ob = nullptr;
00860
00861     delete[] ob_bottom;
00862     ob_bottom = nullptr;
00863   } // End of: for (ll = 0; ll < dim_null; ll++);
00864
00865   #if MTK_DEBUG_LEVEL > 0
00866   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00867   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00868     for (auto jj = 0; jj < dim_null_; ++jj) {
00869       std::cout << std::setw(12) << prem_apps_[ii*dim_null_ + jj];
00870     }
00871     std::cout << std::endl;
00872   }
00873   std::cout << std::endl;
00874   #endif
00875
00876   delete[] gg;
00877   gg = nullptr;
00878
00879   return true;
00880 }
00881
00882 bool mtk::Div1D::ComputeWeights(void) {
00883
00884   // Matrix to copmpute the weights as in the CRSA.
00885   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00886
00888
00889   // Assemble the pi matrix using:
00890   // 1. The collection of scaled preliminary approximations.
00891   // 2. The collection of coefficients approximating at the interior.
00892   // 3. The scaled basis for the null-space.
00893
00894   // 1.1. Process array of scaled preliminary approximations.
00895
00896   // These are queued in scaled_solutions. Each one of these, will be a column
00897   // of the pi matrix:
00898   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00899     for (auto jj = 0; jj < dim_null_; ++jj) {
00900       pi.data()[ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00901         prem_apps_[ii*dim_null_ + jj];
00902     }
00903   }
00904
00905   // 1.2. Add columns from known stencil approximating at the interior.
00906
00907   // However, these must be padded by zeros, according to their position in the
00908   // final pi matrix:
00909   auto mm = 0;
00910   for (auto jj = dim_null_; jj < order_accuracy_; ++jj) {
00911     for (auto ii = 0; ii < order_accuracy_; ++ii) {
```

```
00912       pi.data()[(ii + mm)*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj] =
00913         coeffs_interior_[ii];
00914     }
00915     ++mm;
00916   }
00917
00918   rat_basis_null_space_.OrderColMajor();
00919
00920   #if MTK_DEBUG_LEVEL > 0
00921   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00922   std::cout << rat_basis_null_space_ << std::endl;
00923   #endif
00924
00925   // 1.3. Add final set of columns: rational basis for null-space.
00926   for (auto jj = dim_null_ + (order_accuracy_/2 + 1); jj < num_bndy_coeffs_ - 1; ++jj) {
00927     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00928       auto og =
00929         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00930       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00931       pi.data()[de] = rat_basis_null_space_.data()[og];
00932     }
00933   }
00934
00935   #if MTK_DEBUG_LEVEL >0
00936   std::cout << "coeffs_interior_ =" << std::endl;
00937   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00938     std::cout << std::setw(12) << coeffs_interior_[ii];
00939   }
00940   std::cout << std::endl << std::endl;
00941   #endif
00942
00943   #if MTK_DEBUG_LEVEL >0
00944   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00945   std::cout << pi << std::endl;
00946   #endif
00947
00948
00949
00950   // This imposes the mimetic condition.
00951
00952   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
00953
00954   try {
00955     hh = new mtk::Real[num_bndy_coeffs_];
00956   } catch (std::bad_alloc &memory_allocation_exception) {
00957     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00958       std::endl;
00959     std::cerr << memory_allocation_exception.what() << std::endl;
00960   }
00961   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00962
00963   hh[0] = -mtk::kOne;
00964   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00965     auto aux_xx = mtk::kZero;
00966     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00967       aux_xx += coeffs_interior_[jj];
00968     }
00969     hh[ii] = -mtk::kOne*aux_xx;
00970   }
00971
00973
00974   // That is, we construct a system, to solve for the weights.
00975
00976   // Once again we face the challenge of solving with LAPACK. However, for the
00977   // CRSA, this matrix PI is over-determined, since it has more rows than
00978   // unknowns. However, according to the theory, the solution to this system is
00979   // unique. We will use dgels_.
00980
00981   try {
00982     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
00983   } catch (std::bad_alloc &memory_allocation_exception) {
00984     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00985       std::endl;
00986     std::cerr << memory_allocation_exception.what() << std::endl;
00987   }
00988   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
00989
00990   int weights_ld{pi.num_cols() + 1};
00991
00992   // Preserve hh.
00993   std::copy(hh, hh + weights_ld, weights_cbs_);
00994
```

```
00995   pi.Transpose();
00996
00997   int info{mtk::LAPACKAdapter::SolveRectangularDenseSystem(
      pi, weights_cbs_, weights_ld)};
00998
00999   #if MTK_DEBUG_LEVEL > 0
01000   if (!info) {
01001     std::cout << "System successfully solved!" << std::endl << std::endl;
01002   } else {
01003     std::cerr << "Error solving system! info = " << info << std::endl;
01004   }
01005   #endif
01006
01007   #if MTK_DEBUG_LEVEL > 0
01008   std::cout << "hh =" << std::endl;
01009   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01010     std::cout << std::setw(11) << hh[ii] << std::endl;
01011   }
01012   std::cout << std::endl;
01013   #endif
01014
01015   // Preserve the original weights for research.
01016
01017   try {
01018     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01019   } catch (std::bad_alloc &memory_allocation_exception) {
01020     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01021       std::endl;
01022     std::cerr << memory_allocation_exception.what() << std::endl;
01023   }
01024   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01025
01026   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01027
01028   #if MTK_DEBUG_LEVEL > 0
01029   std::cout << "weights_CRSA + lambda =" << std::endl;
01030   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01031     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01032   }
01033   std::cout << std::endl;
01034   #endif
01035
01037   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyDiv) {
01038
01039     int minrow_{std::numeric_limits<int>::infinity()};
01040
01041     mtk::Real norm_{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01042     mtk::Real minnorm_{std::numeric_limits<mtk::Real>::infinity()};
01043
01045
01046     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01047
01048     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01049       for (auto jj = 0; jj < dim_null_; ++jj) {
01050         phi.data()[ii*(order_accuracy_) + jj] = prem_apps_[ii*dim_null_ + jj];
01051       }
01052     }
01053
01054     int aux{};  // Auxiliary variable.
01055     for (auto jj = dim_null_; jj < dim_null_ + 2; ++jj) {
01056       for (auto ii = 0; ii < order_accuracy_; ++ii) {
01057         phi.data()[(ii + aux)*order_accuracy_ + jj] = coeffs_interior_[ii];
01058       }
01059       ++aux;
01060     }
01061
01062     for(auto jj=order_accuracy_ - 1; jj >=order_accuracy_ - dim_null_; jj--) {
01063       for(auto ii=0; ii<order_accuracy_ + 1; ++ii) {
01064         phi.data()[ii*order_accuracy_+jj] = mtk::kZero;
01065       }
01066     }
01067
01068     for (auto jj = 0; jj < order_accuracy_ + 1; ++jj) {
01069       for (auto ii = 0; ii < dim_null_; ++ii) {
01070         phi.data()[(ii + order_accuracy_ - dim_null_ + jj*order_accuracy_)] =
01071           -prem_apps_[(dim_null_ - ii - 1 + jj*dim_null_)];
01072       }
01073     }
01074
01075     for(auto ii = 0; ii < order_accuracy_/2; ++ii) {
```

```
01076       for (auto jj = dim_null_ + 2; jj < order_accuracy_; ++jj) {
01077         auto swap = phi.data()[ii*order_accuracy_+jj];
01078         phi.data()[ii*order_accuracy_ + jj] =
01079           phi.data()[(order_accuracy_-ii)*order_accuracy_+jj];
01080         phi.data()[(order_accuracy_-ii)*order_accuracy_+jj] = swap;
01081       }
01082     }
01083
01084     #if MTK_DEBUG_LEVEL > 0
01085     std::cout << "Constructed PHI matrix for CBS Algorithm: " << std::endl;
01086     std::cout << phi << std::endl;
01087     #endif
01088
01090
01091     mtk::Real *lamed{};  // Used to build big lambda.
01092
01093     try {
01094       lamed = new mtk::Real[dim_null_];
01095     } catch (std::bad_alloc &memory_allocation_exception) {
01096       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01097         std::endl;
01098       std::cerr << memory_allocation_exception.what() << std::endl;
01099     }
01100     memset(lamed, mtk::kZero, sizeof(lamed[0])*dim_null_);
01101
01102     for (auto ii = 0; ii < dim_null_; ++ii) {
01103       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01104     }
01105
01106     #if MTK_DEBUG_LEVEL > 0
01107     std::cout << "lamed =" << std::endl;
01108     for (auto ii = 0; ii < dim_null_; ++ii) {
01109       std::cout << std::setw(12) << lamed[ii] << std::endl;
01110     }
01111     std::cout << std::endl;
01112     #endif
01113
01114     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01115       mtk::Real temp = mtk::kZero;
01116       for(auto jj = 0; jj < dim_null_; ++jj) {
01117         temp = temp +
01118           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01119       }
01120       hh[ii] = hh[ii] - temp;
01121     }
01122
01123     #if MTK_DEBUG_LEVEL > 0
01124     std::cout << "big_lambda =" << std::endl;
01125     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01126       std::cout << std::setw(12) << hh[ii] << std::endl;
01127     }
01128     std::cout << std::endl;
01129     #endif
01130
01131     int copy_result{};
01132
01133     mtk::Real normerr_; // Norm of the error for the solution on each row.
01134
01136
01137     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01138       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
    data(),
01139                                                           order_accuracy_ + 1,
01140                                                           order_accuracy_,
01141                                                           order_accuracy_,
01142                                                           hh,
01143                                                           weights_cbs_,
01144                                                           row_,
01145                                                           mimetic_threshold_,
01146                                                           copy_result);
01147       mtk::Real aux{normerr_/norm_};
01148
01149       #if MTK_DEBUG_LEVEL>0
01150       std::cout << "Relative norm: " << aux << " " << std::endl;
01151       std::cout << std::endl;
01152       #endif
01153
01154       if (aux < minnorm_) {
01155         minnorm_ = aux;
01156         minrow_= row_;
01157       }
```

```
01158     }
01159
01160     #if MTK_DEBUG_LEVEL > 0
01161     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01162       std::endl;
01163     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01164       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01165     }
01166     std::cout << std::endl;
01167     #endif
01168
01170
01171     // After we know which row yields the smallest relative norm that row is
01172     // chosen to be the objective function and the result of the optimizer is
01173     // chosen to be the new weights_.
01174
01175     #if MTK_DEBUG_LEVEL > 0
01176     std::cout << "Minimum Relative Norm " << minnorm_ << " found at row " <<
01177       minrow_ + 1 << std::endl;
01178     std::cout << std::endl;
01179     #endif
01180
01181     copy_result = 1;
01182     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01183                                                         order_accuracy_ + 1,
01184                                                         order_accuracy_,
01185                                                         order_accuracy_,
01186                                                         hh,
01187                                                         weights_cbs_,
01188                                                         minrow_,
01189                                                         mimetic_threshold_,
01190                                                         copy_result);
01191     mtk::Real aux_{normerr_/norm_};
01192     #if MTK_DEBUG_LEVEL > 0
01193     std::cout << "Relative norm: " << aux_ << std::endl;
01194     std::cout << std::endl;
01195     #endif
01196
01197     delete [] lamed;
01198     lamed = nullptr;
01199   }
01200
01201   delete [] hh;
01202   hh = nullptr;
01203
01204   return true;
01205 }
01206
01207 bool mtk::Div1D::ComputeStencilBoundaryGrid(void) {
01208
01209   #if MTK_DEBUG_LEVEL > 0
01210   std::cout << "weights_CBSA + lambda =" << std::endl;
01211   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01212     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01213   }
01214   std::cout << std::endl;
01215   #endif
01216
01218
01219   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01220
01221   try {
01222     lambda = new mtk::Real[dim_null_];
01223   } catch (std::bad_alloc &memory_allocation_exception) {
01224     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01225       std::endl;
01226     std::cerr << memory_allocation_exception.what() << std::endl;
01227   }
01228   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01229
01230   for (auto ii = 0; ii < dim_null_; ++ii) {
01231     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01232   }
01233
01234   #if MTK_DEBUG_LEVEL > 0
01235   std::cout << "lambda =" << std::endl;
01236   for (auto ii = 0; ii < dim_null_; ++ii) {
01237     std::cout << std::setw(12) << lambda[ii] << std::endl;
01238   }
01239   std::cout << std::endl;
```

```
01240   #endif
01241
01243
01244   mtk::Real *alpha{}; // Collection of alpha values.
01245
01246   try {
01247     alpha = new mtk::Real[dim_null_];
01248   } catch (std::bad_alloc &memory_allocation_exception) {
01249     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01250       std::endl;
01251     std::cerr << memory_allocation_exception.what() << std::endl;
01252   }
01253   memset(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01254
01255   for (auto ii = 0; ii < dim_null_; ++ii) {
01256     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01257   }
01258
01259   #if MTK_DEBUG_LEVEL > 0
01260   std::cout << "alpha =" << std::endl;
01261   for (auto ii = 0; ii < dim_null_; ++ii) {
01262     std::cout << std::setw(12) << alpha[ii] << std::endl;
01263   }
01264   std::cout << std::endl;
01265   #endif
01266
01268
01269   try {
01270     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*dim_null_];
01271   } catch (std::bad_alloc &memory_allocation_exception) {
01272     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01273       std::endl;
01274     std::cerr << memory_allocation_exception.what() << std::endl;
01275   }
01276   memset(mim_bndy_, mtk::kZero, sizeof(mim_bndy_[0])*num_bndy_coeffs_*dim_null_);
01277
01278   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01279     for (auto jj = 0; jj < dim_null_; ++jj) {
01280       mim_bndy_[ii*dim_null_ + jj] =
01281         prem_apps_[ii*dim_null_ + jj] +
01282         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01283     }
01284   }
01285
01286   #if MTK_DEBUG_LEVEL >0
01287   std::cout << "Collection of mimetic approximations:" << std::endl;
01288   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01289     for (auto jj = 0; jj < dim_null_; ++jj) {
01290       std::cout << std::setw(13) << mim_bndy_[ii*dim_null_ + jj];
01291     }
01292     std::cout << std::endl;
01293   }
01294   std::cout << std::endl;
01295   #endif
01296
01297   delete[] lambda;
01298   lambda = nullptr;
01299
01300   delete[] alpha;
01301   alpha = nullptr;
01302
01303   return true;
01304 }
01305
01306 bool mtk::Div1D::AssembleOperator(void) {
01307
01308   // The output array will have this form:
01309   // 1. The first entry of the array will contain the used order order_accuracy_.
01310   // 2. The second entry of the array will contain the collection of
01311   // approximating coefficients for the interior of the grid.
01312   // 3. IF order_accuracy_ > 2, then the third entry will contain a collection of weights.
01313   // 4. IF order_accuracy_ > 2, the next dim_null_ entries will contain the collections of
01314   // approximating coefficients for the west boundary of the grid.
01315
01316   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01317     divergence_length_ =
01318       1 + order_accuracy_ + order_accuracy_ + dim_null_*num_bndy_coeffs_;
01319   } else {
01320     divergence_length_ = 1 + order_accuracy_;
01321   }
01322
```

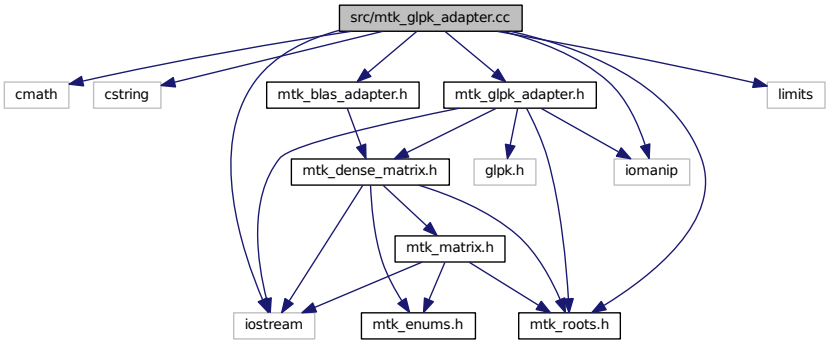
```
01323   #if MTK_DEBUG_LEVEL > 0
01324   std::cout << "divergence_length_ = " << divergence_length_ << std::endl;
01325   #endif
01326
01327   try {
01328     divergence_ = new double[divergence_length_];
01329   } catch (std::bad_alloc &memory_allocation_exception) {
01330     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01331       std::endl;
01332     std::cerr << memory_allocation_exception.what() << std::endl;
01333   }
01334   memset(divergence_, mtk::kZero, sizeof(divergence_[0])*divergence_length_);
01335
01337
01338   divergence_[0] = order_accuracy_;
01339
01341
01342   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01343   divergence_[ii + 1] = coeffs_interior_[ii];
01344   }
01345
01347
01348   if (order_accuracy_ > 2) {
01349     for (auto ii = 0; ii < order_accuracy_; ++ii) {
01350       divergence_[(1 + order_accuracy_) + ii] = weights_cbs_[ii];
01351     }
01352   }
01353
01356
01357   if (order_accuracy_ > 2) {
01358     auto offset = (2*order_accuracy_ + 1);
01359     int mm{};
01360     for (auto ii = 0; ii < dim_null_; ++ii) {
01361       for (auto jj = 0; jj < num_bndy_coeffs_; ++jj) {
01362         divergence_[offset + (mm)] = mim_bndy_[jj*dim_null_ + ii];
01363         ++mm;
01364       }
01365     }
01366   }
01367
01368   #if MTK_DEBUG_LEVEL > 0
01369   std::cout << "1D " << order_accuracy_ << "-order div built!" << std::endl;
01370   std::cout << std::endl;
01371   #endif
01372
01373   return true;
01374 }
```

17.39 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:



17.39.1 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

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Todo Document better this file.

Definition in file mtk_glpk_adapter.cc.

17.40 mtk_glpk_adapter.cc

```
00001
00021 /*
00022 Copyright (C) 2015, Computational Science Research Center, San Diego State
00023 University. All rights reserved.
00024
00025 Redistribution and use in source and binary forms, with or without modification,
00026 are permitted provided that the following conditions are met:
00027
00028 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00029 and a copy of the modified files should be reported once modifications are
00030 completed. Documentation related to said modifications should be included.
00031
00032 2. Redistributions of source code must be done through direct
00033 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00034
00035 3. Redistributions of source code must retain the above copyright notice, this
```

```
00036 list of conditions and the following disclaimer.
00037
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00041
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00061 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00062 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00063 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00064 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00065 */
00066
00067 #include <cmath>
00068 #include <cstring>
00069
00070 #include <iostream>
00071 #include <iomanip>
00072 #include <limits>
00073
00074 #include "mtk_roots.h"
00075 #include "mtk_blas_adapter.h"
00076 #include "mtk_glpk_adapter.h"
00077
00078 mtk::Real mtk::GLPKAdapter::SolveSimplexAndCompare(
      mtk::Real *A,
00079                                                    int nrows,
00080                                                    int ncols,
00081                                                    int kk,
00082                                                    mtk::Real *hh,
00083                                                    mtk::Real *qq,
00084                                                    int robjective,
00085                                                    mtk::Real mimetic_threshold,
00086                                                    int copy) {
00087
00088   #if MTK_DEBUG_LEVEL > 0
00089   char mps_file_name[18]; //  File name for the MPS files.
00090   #endif
00091   char rname[5];          //
00092   char cname[5];          //
00093
00094   glp_prob *lp; // Linear programming problem.
00095
00096   int *ia;  //
00097   int *ja;  //
00098
00099   int problem_size; // Size of the problem.
00100   int lp_nrows;     // Number of rows.
00101   int lp_ncols;     // Number of columns.
00102   int matsize;      //
00103   int glp_index{1};    // Index of the objective function.
00104   int ii;           //
00105   int jj;           //
00106
00107   mtk::Real *ar;            //
00108   mtk::Real *objective;     //
00109   mtk::Real *rhs;           //
00110   mtk::Real *err;           //
00111   mtk::Real xl;             //
00112
00113   #if MTK_DEBUG_LEVEL > 0
00114   mtk::Real obj_value;      //
00115   #endif
```

```
00116
00117   lp_nrows = kk;
00118   lp_ncols = kk;
00119
00120   matsize = lp_nrows*lp_ncols;
00121
00123
00125   problem_size = lp_nrows*lp_ncols + 1;
00126
00127   try {
00128     ia = new int[problem_size];
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(ia, 0, sizeof(ia[0])*problem_size);
00135
00136   try {
00137     ja = new int[problem_size];
00138   } catch (std::bad_alloc &memory_allocation_exception) {
00139     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00140       std::endl;
00141     std::cerr << memory_allocation_exception.what() << std::endl;
00142   }
00143   memset(ja, 0, sizeof(ja[0])*problem_size);
00144
00145   try {
00146     ar = new mtk::Real[problem_size];
00147   } catch (std::bad_alloc &memory_allocation_exception) {
00148     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00149       std::endl;
00150     std::cerr << memory_allocation_exception.what() << std::endl;
00151   }
00152   memset(ar, mtk::kZero, sizeof(ar[0])*problem_size);
00153
00154   try {
00155     objective = new mtk::Real[lp_ncols + 1];
00156   } catch (std::bad_alloc &memory_allocation_exception) {
00157     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00158       std::endl;
00159     std::cerr << memory_allocation_exception.what() << std::endl;
00160   }
00161   memset(objective, mtk::kZero, sizeof(objective[0])*(lp_ncols + 1));
00162
00163   try {
00164     rhs = new mtk::Real[lp_nrows + 1];
00165   } catch (std::bad_alloc &memory_allocation_exception) {
00166     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00167       std::endl;
00168     std::cerr << memory_allocation_exception.what() << std::endl;
00169   }
00170   memset(rhs, mtk::kZero, sizeof(rhs[0])*(lp_nrows + 1));
00171
00172   try {
00173     err = new mtk::Real[lp_nrows];
00174   } catch (std::bad_alloc &memory_allocation_exception) {
00175     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00176       std::endl;
00177     std::cerr << memory_allocation_exception.what() << std::endl;
00178   }
00179   memset(err, mtk::kZero, sizeof(err[0])*(lp_nrows));
00180
00181   #if MTK_DEBUG_LEVEL > 0
00182   std::cout << "Problem size: " << problem_size << std::endl;
00183   std::cout << "lp_nrows = " << lp_nrows << std::endl;
00184   std::cout << "lp_ncols = " << lp_ncols << std::endl;
00185   std::cout << std::endl;
00186   #endif
00187
00188   lp = glp_create_prob();
00189
00190   glp_set_prob_name (lp, "mtk::GLPKAdapter::Simplex");
00191
00192   glp_set_obj_dir (lp, GLP_MIN);
00193
00195
00196   glp_add_rows(lp, lp_nrows);
00197
00198   for (ii = 1; ii <= lp_nrows; ++ii) {
00199     sprintf(rname, "R%02d",ii);
```

```
00200     glp_set_row_name(lp, ii, rname);
00201   }
00202
00203   glp_add_cols(lp, lp_ncols);
00204
00205   for (ii = 1; ii <= lp_ncols; ++ii) {
00206     sprintf(cname, "Q%02d",ii);
00207     glp_set_col_name (lp, ii, cname);
00208   }
00209
00211
00212   #if MTK_DEBUG_LEVEL>0
00213   std::cout << "Using row " << robjective + 1 << " as objective." << std::endl;
00214   #endif
00215   for (jj = 0; jj < kk; ++jj) {
00216     objective[glp_index] = A[jj + robjective * ncols];
00217     glp_index++;
00218   }
00219   #if MTK_DEBUG_LEVEL >0
00220   std::cout << std::endl;
00221   #endif
00222
00224
00225   glp_index = 1;
00226   rhs[0] = mtk::kZero;
00227   for (ii = 0; ii <= lp_nrows; ++ii) {
00228     if (ii != robjective) {
00229       rhs[glp_index] = hh[ii];
00230       glp_set_row_bnds(lp, glp_index, GLP_UP, 0.0, rhs[glp_index]);
00231       glp_index++;
00232     }
00233   }
00234
00235   #if MTK_DEBUG_LEVEL > 0
00236   std::cout << "rhs =" << std::endl;
00237   for (auto ii = 0; ii < lp_nrows; ++ii) {
00238     std::cout << std::setw(15) << rhs[ii] << std::endl;
00239   }
00240   std::cout << std::endl;
00241   #endif
00242
00244
00245   for (ii = 1; ii <= lp_ncols; ++ii) {
00246     glp_set_obj_coef (lp, ii, objective[ii]);
00247   }
00248
00250
00251   for (ii = 1; ii <= lp_ncols; ++ii) {
00252     glp_set_col_bnds (lp, ii, GLP_LO, mimetic_threshold, 0.0);
00253   }
00254
00256
00257   glp_index = 1;
00258   for (ii = 0; ii <= kk; ++ii) {
00259     for (jj = 0; jj < kk; ++jj) {
00260       if (ii != robjective) {
00261         ar[glp_index] = A[jj + ii * ncols];
00262         glp_index++;
00263       }
00264     }
00265   }
00266
00267   glp_index = 0;
00268
00269   for (ii = 1; ii < problem_size; ++ii) {
00270     if (((ii - 1) % lp_ncols) == 0) {
00271       glp_index++;
00272     }
00273     ia[ii] = glp_index;
00274     ja[ii] = (ii - 1) % lp_ncols + 1;
00275   }
00276
00277   glp_load_matrix (lp, matsize, ia, ja, ar);
00278
00279   #if MTK_DEBUG_LEVEL > 0
00280   sprintf(mps_file_name, "LP_MPS_row_%02d.mps", robjective);
00281   glp_write_mps(lp, GLP_MPS_FILE, nullptr, mps_file_name);
00282   #endif
00283
00285
00286   glp_simplex (lp, nullptr);
```

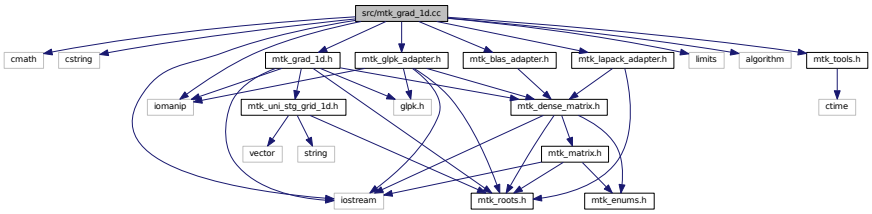
```
00287
00288   // Check status of the solution.
00289
00290   if (glp_get_status(lp) == GLP_OPT) {
00291
00292     for(ii = 1; ii <= lp_ncols; ++ii) {
00293       err[ii - 1] = qq[ii - 1] - glp_get_col_prim(lp,ii);
00294     }
00295
00296     #if MTK_DEBUG_LEVEL > 0
00297     obj_value = glp_get_obj_val (lp);
00298     std::cout << std::setw(12) << "CBS" << std::setw(12) << "CRS" << std::endl;
00299     for (ii = 0; ii < lp_ncols; ++ii) {
00300       std::cout << "q_" << ii + 1 << " = " << std::setw(12) <<
00301         glp_get_col_prim(lp,ii + 1) << std::setw(12) << qq[ii] << std::endl;
00302     }
00303     std::cout << "Objective function value (row " << robjective + 1 << ") = " <<
00304       obj_value << std::endl;
00305     #endif
00306
00307     if (copy) {
00308       for(ii = 0; ii < lp_ncols; ++ii) {
00309         qq[ii] = glp_get_col_prim(lp,ii + 1);
00310       }
00311       // Preserve the bottom values of qq.
00312     }
00313
00314     x1 = mtk::BLASAdapter::RealNRM2(err,lp_ncols);
00315
00316   } else {
00317     x1 = std::numeric_limits<mtk::Real>::infinity();
00318   }
00319
00320   glp_delete_prob (lp);
00321   glp_free_env ();
00322
00323   delete [] ia;
00324   delete [] ja;
00325   delete [] ar;
00326   delete [] objective;
00327   delete [] rhs;
00328   delete [] err;
00329
00330   return x1;
00331 }
```

17.41 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)

17.41.1 Detailed Description

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

Author

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Todo Overload ostream operator as in mtk::Lap1D.

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

Definition in file mtk_grad_1d.cc.

17.42 mtk_grad_1d.cc

```
00001
00015 /*
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00017 University. All rights reserved.
00018
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00020 are permitted provided that the following conditions are met:
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. Documentation related to said modifications should be included.
00025
00026 2. Redistributions of source code must be done through direct
00027 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00028
00029 3. Redistributions of source code must retain the above copyright notice, this
00030 list of conditions and the following disclaimer.
```

```
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00051 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
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00054 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
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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_grad_1d.h"
00076
00077 namespace mtk {
00078
00079 std::ostream& operator <<(std::ostream &stream, mtk::Grad1D &in) {
00080
00082
00083   stream << "gradient_[0] = " << std::setw(9) << in.gradient_[0] << std::endl;
00084
00086
00087   stream << "gradient_[1:" << in.order_accuracy_ << "] = ";
00088   for (auto ii = 1; ii <= in.order_accuracy_; ++ii) {
00089     stream << std::setw(9) << in.gradient_[ii] << " ";
00090   }
00091   stream << std::endl;
00092
00094
00095   stream << "gradient_[" << in.order_accuracy_ + 1 << ":" <<
00096     2*in.order_accuracy_ << "] = ";
00097   for (auto ii = in.order_accuracy_ + 1; ii <= 2*in.
      order_accuracy_; ++ii) {
00098     stream << std::setw(9) << in.gradient_[ii] << " ";
00099   }
00100   stream << std::endl;
00101
00103
00104   int offset{2*in.order_accuracy_ + 1};
00105   int mm {};
00106
00107   stream << "gradient_[" << offset + mm << ":" <<
00108     offset + mm + in.num_bndy_coeffs_ - 1 << "] = ";
00109
00110   if (in.order_accuracy_ > mtk::kDefaultOrderAccuracy) {
00111     for (auto ii = 0; ii < in.num_bndy_approxs_ ; ++ii) {
00112       for (auto jj = 0; jj < in.num_bndy_coeffs_; jj++) {
00113         auto value = in.gradient_[offset + (mm)];
00114         stream << std::setw(9) << value << " ";
```

```
00115         mm++;
00116       }
00117     }
00118   } else {
00119     stream << std::setw(9) << in.gradient_[offset + 0] << ' ';
00120     stream << std::setw(9) << in.gradient_[offset + 1] << ' ';
00121     stream << std::setw(9) << in.gradient_[offset + 2] << ' ';
00122   }
00123   stream << std::endl;
00124 
00125   return stream;
00126 }
00127 }
00128 
00129 mtk::Grad1D::Grad1D():
00130   order_accuracy_(mtk::kDefaultOrderAccuracy),
00131   dim_null_(),
00132   num_bndy_approxs_(),
00133   num_bndy_coeffs_(),
00134   gradient_length_(),
00135   minrow_(),
00136   row_(),
00137   coeffs_interior_(),
00138   prem_apps_(),
00139   weights_crs_(),
00140   weights_cbs_(),
00141   mim_bndy_(),
00142   gradient_(),
00143   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00144 
00145 mtk::Grad1D::Grad1D(const Grad1D &grad):
00146   order_accuracy_(grad.order_accuracy_),
00147   dim_null_(grad.dim_null_),
00148   num_bndy_approxs_(grad.num_bndy_approxs_),
00149   num_bndy_coeffs_(grad.num_bndy_coeffs_),
00150   gradient_length_(grad.gradient_length_),
00151   minrow_(grad.minrow_),
00152   row_(grad.row_),
00153   coeffs_interior_(grad.coeffs_interior_),
00154   prem_apps_(grad.prem_apps_),
00155   weights_crs_(grad.weights_crs_),
00156   weights_cbs_(grad.weights_cbs_),
00157   mim_bndy_(grad.mim_bndy_),
00158   gradient_(grad.gradient_),
00159   mimetic_threshold_(grad.mimetic_threshold_) {}
00160 
00161 mtk::Grad1D::~Grad1D() {
00162 
00163   delete[] coeffs_interior_;
00164   coeffs_interior_ = nullptr;
00165 
00166   delete[] prem_apps_;
00167   prem_apps_ = nullptr;
00168 
00169   delete[] weights_crs_;
00170   weights_crs_ = nullptr;
00171 
00172   delete[] weights_cbs_;
00173   weights_cbs_ = nullptr;
00174 
00175   delete[] mim_bndy_;
00176   mim_bndy_ = nullptr;
00177 
00178   delete[] gradient_;
00179   gradient_ = nullptr;
00180 }
00181 
00182 bool mtk::Grad1D::ConstructGrad1D(int order_accuracy,
      Real mimetic_threshold) {
00183 
00184   #if MTK_DEBUG_LEVEL > 0
00185   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00186   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00187   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00188                       __FILE__, __LINE__, __func__);
00189 
00190   if (order_accuracy >= mtk::kCriticalOrderAccuracyGrad) {
00191     std::cout << "WARNING: Numerical accuracy is high." << std::endl;;
00192   }
00193 
00194   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;;
```

```
00195   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;;
00196   #endif
00197
00198   order_accuracy_ = order_accuracy;
00199   mimetic_threshold_ = mimetic_threshold;
00200
00202
00203   bool abort_construction = ComputeStencilInteriorGrid();
00204
00205   #if MTK_DEBUG_LEVEL > 0
00206   if (!abort_construction) {
00207     std::cerr << "Could NOT complete stage 1." << std::endl;;
00208     std::cerr << "Exiting..." << std::endl;;
00209     return false;
00210   }
00211   #endif
00212
00213   // At this point, we already have the values for the interior stencil stored
00214   // in the coeffs_interior_ array.
00215
00216   dim_null_ = order_accuracy_/2 - 1;
00217
00218   num_bndy_approxs_ = dim_null_ + 1;
00219
00220   #ifdef MTK_PRECISION_DOUBLE
00221   num_bndy_coeffs_ = (int) (3.0*((mtk::Real) order_accuracy_)/2.0);
00222   #else
00223   num_bndy_coeffs_ = (int) (3.0f*((mtk::Real) order_accuracy_)/2.0f);
00224   #endif
00225
00227
00228   // For this we will follow recommendations given in:
00229   //
00230   // http://icl.cs.utk.edu/lapack-forum/viewtopic.php?f=5&t=4506
00231   //
00232   // We will compute the QR Factorization of the transpose, as in the
00233   // following (MATLAB) pseudo-code:
00234   //
00235   // [Q,R] = qr(V'); % Full QR as defined in
00236   // % http://www.stanford.edu/class/ee263/notes/qr_matlab.pdf
00237   //
00238   // null-space = Q(:, last (order_accuracy_/2 - 1) columns of Q );
00239   //
00240   // However, given the nature of the Vandermonde matrices we've just
00241   // computed, they all posses the same null-space. Therefore, we impose the
00242   // convention of computing the null-space of the first Vandermonde matrix
00243   // (west boundary).
00244
00245   // In the case of the gradient, the first Vandermonde system has a unique
00246   // solution for the case of second-order-accuracy. Ergo, the Vandermonde
00247   // matrix used to assemble said system, will have an empty null-space.
00248
00249   // Therefore, we only compute a rational basis for the case of order higher
00250   // than second.
00251
00252   if (dim_null_ > 0) {
00253
00254     abort_construction = ComputeRationalBasisNullSpace();
00255
00256     #if MTK_DEBUG_LEVEL > 0
00257     if (!abort_construction) {
00258       std::cerr << "Could NOT complete stage 2.1." << std::endl;;
00259       std::cerr << "Exiting..." << std::endl;;
00260       return false;
00261     }
00262     #endif
00263   }
00264
00266
00267   abort_construction = ComputePreliminaryApproximations();
00268
00269   #if MTK_DEBUG_LEVEL > 0
00270   if (!abort_construction) {
00271     std::cerr << "Could NOT complete stage 2.2." << std::endl;;
00272     std::cerr << "Exiting..." << std::endl;;
00273     return false;
00274   }
00275   #endif
00276
00278
00279   abort_construction = ComputeWeights();
```

```
00280
00281   #if MTK_DEBUG_LEVEL > 0
00282   if (!abort_construction) {
00283     std::cerr << "Could NOT complete stage 2.3." << std::endl;;
00284     std::cerr << "Exiting..." << std::endl;;
00285     return false;
00286   }
00287   #endif
00288
00290
00291   if (dim_null_ > 0) {
00292
00293     abort_construction = ComputeStencilBoundaryGrid();
00294
00295     #if MTK_DEBUG_LEVEL > 0
00296     if (!abort_construction) {
00297       std::cerr << "Could NOT complete stage 2.4." << std::endl;;
00298       std::cerr << "Exiting..." << std::endl;;
00299       return false;
00300     }
00301     #endif
00302   }
00303
00305
00306   // Once we have the following three collections of data:
00307   //   (a) the coefficients for the interior,
00308   //   (b) the coefficients for the boundary (if it applies),
00309   //   (c) and the weights (if it applies),
00310   // we will store everything in the output array:
00311
00312   abort_construction = AssembleOperator();
00313
00314   #if MTK_DEBUG_LEVEL > 0
00315   if (!abort_construction) {
00316     std::cerr << "Could NOT complete stage 3." << std::endl;;
00317     std::cerr << "Exiting..." << std::endl;;
00318     return false;
00319   }
00320   #endif
00321
00322   return true;
00323 }
00324
00325 mtk::Real *mtk::Grad1D::weights_crs() {
00326
00327   return weights_crs_;
00328 }
00329
00330 mtk::Real *mtk::Grad1D::weights_cbs() {
00331
00332   return weights_cbs_;
00333 }
00334
00335 mtk::DenseMatrix mtk::Grad1D::ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) {
00336
00337   int nn{grid.num_cells_x()}; // Number of cells on the grid.
00338
00339   #if MTK_DEBUG_LEVEL > 0
00340   mtk::Tools::Prevent(order_accuracy_ <= 0, __FILE__, __LINE__, __func__);
00341
00343
00344   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 2, __FILE__, __LINE__, __func__);
00345   #endif
00346
00347   mtk::Real inv_delta_x{mtk::kOne/grid.delta_x()};
00348
00349   int gg_num_rows = nn + 1;
00350   int gg_num_cols = nn + 2;
00351   int elements_per_row = num_bndy_coeffs_;
00352   int num_extra_rows = order_accuracy_/2;
00353
00354   // Output matrix featuring sizes for gradient operators.
00355   mtk::DenseMatrix out(gg_num_rows, gg_num_cols);
00356
00358
00359   auto ee_index = 0;
00360   for (auto ii = 0; ii < num_extra_rows; ii++) {
00361     auto cc = 0;
00362     for(auto jj = 0 ; jj < gg_num_cols; jj++) {
00363       if(cc >= elements_per_row) {
```

```
00364         out.SetValue(ii, jj, mtk::kZero);
00365       } else {
00366         out.SetValue(ii,jj,
00367                      gradient_[2*order_accuracy_ + 1 + ee_index++]*inv_delta_x);
00368         cc++;
00369       }
00370     }
00371   }
00372
00374
00375   for (auto ii = num_extra_rows; ii < gg_num_rows - num_extra_rows; ii++) {
00376     auto jj = ii - num_extra_rows + 1;
00377     for (auto cc = 0; cc < order_accuracy_; cc++, jj++) {
00378       out.SetValue(ii, jj, coeffs_interior_[cc]*inv_delta_x);
00379     }
00380   }
00381
00383
00384   ee_index = 0;
00385   for (auto ii = gg_num_rows - 1; ii >= gg_num_rows - num_extra_rows; ii--) {
00386     auto cc = 0;
00387     for (auto jj = gg_num_cols - 1; jj >= 0; 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   return out;
00399 }
00400
00401 bool mtk::Grad1D::ComputeStencilInteriorGrid() {
00402
00404
00405   mtk::Real* pp{}; // Spatial coordinates to create interior stencil.
00406
00407   try {
00408     pp = new mtk::Real[order_accuracy_];
00409   } catch (std::bad_alloc &memory_allocation_exception) {
00410     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00411       std::endl;
00412     std::cerr << memory_allocation_exception.what() << std::endl;
00413   }
00414   memset(pp, mtk::kZero, sizeof(pp[0])*order_accuracy_);
00415
00416   #ifdef MTK_PRECISION_DOUBLE
00417   pp[0] = 1.0/2.0 - ((mtk::Real) order_accuracy_)/2.0;
00418   #else
00419   pp[0] = 1.0f/2.0f - ((mtk::Real) order_accuracy_)/2.0f;
00420   #endif
00421
00422   for (auto ii = 1; ii < order_accuracy_; ++ii) {
00423     pp[ii] = pp[ii - 1] + mtk::kOne;
00424   }
00425
00426   #if MTK_DEBUG_LEVEL > 0
00427   std::cout << "pp =" << std::endl;
00428   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00429     std::cout << std::setw(12) << pp[ii];
00430   }
00431   std::cout << std::endl << std::endl;
00432   #endif
00433
00435
00436   bool transpose{false};
00437
00438   mtk::DenseMatrix vander_matrix(pp,order_accuracy_,order_accuracy_,transpose);
00439
00440   #if MTK_DEBUG_LEVEL > 0
00441   std::cout << "vander_matrix = " << std::endl;
00442   std::cout << vander_matrix << std::endl << std::endl;
00443   #endif
00444
00446
00447   try {
00448     coeffs_interior_ = new mtk::Real[order_accuracy_];
00449   } catch (std::bad_alloc &memory_allocation_exception) {
```

```
00450     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00451       std::endl;
00452     std::cerr << memory_allocation_exception.what() << std::endl;
00453   }
00454   memset(coeffs_interior_, mtk::kZero, sizeof(coeffs_interior_[0])*order_accuracy_);
00455
00456   coeffs_interior_[1] = mtk::kOne;
00457
00458   #if MTK_DEBUG_LEVEL > 0
00459   std::cout << "oo =" << std::endl;
00460   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00461     std::cout << std::setw(12) << coeffs_interior_[ii] << std::endl;
00462   }
00463   std::cout << std::endl;
00464   #endif
00465
00467
00468   int info{mtk::LAPACKAdapter::SolveDenseSystem(vander_matrix,
00469                                                 coeffs_interior_)};
00470
00471   #if MTK_DEBUG_LEVEL > 0
00472   if (!info) {
00473     std::cout << "System solved! Interior stencil attained!" << std::endl;
00474     std::cout << std::endl;
00475   }
00476   else {
00477     std::cerr << "Something wrong solving system! info = " << info << std::endl;
00478     std::cerr << "Exiting..." << std::endl;
00479     return false;
00480   }
00481   #endif
00482
00483   #if MTK_DEBUG_LEVEL > 0
00484   std::cout << "coeffs_interior_ =" << std::endl;
00485   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00486     std::cout << std::setw(12) << coeffs_interior_[ii];
00487   }
00488   std::cout << std::endl << std::endl;
00489   #endif
00490
00491   delete [] pp;
00492   pp = nullptr;
00493
00494   return true;
00495 }
00496
00497 bool mtk::Grad1D::ComputeRationalBasisNullSpace(void) {
00498
00500
00501   mtk::Real* gg{}; // Generator vector for the first Vandermonde matrix.
00502
00503   try {
00504     gg = new mtk::Real[num_bndy_coeffs_];
00505   } catch (std::bad_alloc &memory_allocation_exception) {
00506     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00507       std::endl;
00508     std::cerr << memory_allocation_exception.what() << std::endl;
00509   }
00510   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00511
00512   #ifdef MTK_PRECISION_DOUBLE
00513   gg[1] = 1.0/2.0;
00514   #else
00515   gg[1] = 1.0f/2.0f;
00516   #endif
00517   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00518     gg[ii] = gg[ii - 1] + mtk::kOne;
00519   }
00520
00521   #if MTK_DEBUG_LEVEL > 0
00522   std::cout << "gg =" << std::endl;
00523   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00524     std::cout << std::setw(12) << gg[ii];
00525   }
00526   std::cout << std::endl << std::endl;
00527   #endif
00528
00530
00531   bool tran{true}; // Should I transpose the Vandermonde matrix.
00532
00533   mtk::DenseMatrix aa_west_t(gg, num_bndy_coeffs_, order_accuracy_ + 1, tran);
```

```
00534
00535   #if MTK_DEBUG_LEVEL > 0
00536   std::cout << "aa_west_t =" << std::endl;
00537   std::cout << aa_west_t << std::endl;
00538   #endif
00539
00541
00542   mtk::DenseMatrix qq_t(mtk::LAPACKAdapter::QRFactorDenseMatrix
      (aa_west_t));
00543
00544   #if MTK_DEBUG_LEVEL > 0
00545   std::cout << "qq_t = " << std::endl;
00546   std::cout << qq_t << std::endl;
00547   #endif
00548
00550
00551   int kk_num_rows{num_bndy_coeffs_};
00552   int kk_num_cols{dim_null_};
00553
00554   mtk::DenseMatrix kk(kk_num_rows, kk_num_cols);
00555
00556   // In the case of the gradient, even though we must solve for a null-space
00557   // of dimension 2, we must only extract ONE basis for the kernel.
00558   // We perform this extraction here:
00559
00560   int aux_{kk_num_rows - kk_num_cols};
00561   for (auto ii = kk_num_rows - kk_num_cols; ii < kk_num_rows; ii++) {
00562     aux_--;
00563     for (auto jj = 0; jj < kk_num_rows; jj++) {
00564       kk.data()[jj*kk_num_cols + (kk_num_rows - kk_num_cols - aux_ - 1)] =
00565         qq_t.data()[ii*num_bndy_coeffs_ + jj];
00566     }
00567   }
00568
00569   #if MTK_DEBUG_LEVEL > 0
00570   std::cout << "kk =" << std::endl;
00571   std::cout << kk << std::endl;
00572   std::cout << "kk.num_rows() = " << kk.num_rows() << std::endl;
00573   std::cout << "kk.num_cols() = " << kk.num_cols() << std::endl;
00574   std::cout << std::endl;
00575   #endif
00576
00578
00579   // Scale thus requesting that the last entries of the attained basis for the
00580   // null-space, adopt the pattern we require.
00581   // Essentially we will implement the following MATLAB pseudo-code:
00582   //  scalers = kk(num_bndy_approxs - (dim_null - 1):num_bndy_approxs,:)\B
00583   //  SK = kk*scalers
00584   // where SK is the scaled null-space.
00585
00586   // In this point, we almost have all the data we need correctly allocated
00587   // in memory. We will create the matrix iden_, and elements we wish to scale in
00588   // the kk array. Using the concept of the leading dimension, we could just
00589   // use kk, with the correct leading dimension and that is it. BUT I DO NOT
00590   // GET how does it work. So I will just create a matrix with the content of
00591   // this array that we need, solve for the scalers and then scale the
00592   // whole kk:
00593
00594   // We will then create memory for that sub-matrix of kk (subk).
00595
00596   mtk::DenseMatrix subk(dim_null_, dim_null_);
00597
00598   auto zz = 0;
00599   for (auto ii = order_accuracy_ + 1; ii < num_bndy_coeffs_; ii++) {
00600     for (auto jj = 0; jj < dim_null_; jj++) {
00601       subk.data()[zz*(dim_null_) + jj] = kk.data()[ii*(dim_null_) + jj];
00602     }
00603     zz++;
00604   }
00605
00606   #if MTK_DEBUG_LEVEL > 0
00607   std::cout << "subk =" << std::endl;
00608   std::cout << subk << std::endl;
00609   #endif
00610
00611   subk.Transpose();
00612
00613   #if MTK_DEBUG_LEVEL > 0
00614   std::cout << "subk_t =" << std::endl;
00615   std::cout << subk << std::endl;
00616   #endif
```

```
00617
00618   bool padded{false};
00619   tran = false;
00620
00621   mtk::DenseMatrix iden(dim_null_, padded, tran);
00622
00623   #if MTK_DEBUG_LEVEL > 0
00624   std::cout << "iden =" << std::endl;
00625   std::cout << iden << std::endl;
00626   #endif
00627
00628   // Solve the system to compute the scalers.
00629   // An example of the system to solve, for k = 8, is:
00630   //
00631   // subk*scalers = iden or
00632   //
00633   // |  0.386018  -0.0339244   -0.129478 |           | 1 0 0 |
00634   // | -0.119774   0.0199423   0.0558632 |*scalers = | 0 1 0 |
00635   // | 0.0155708 -0.00349546 -0.00853182 |           | 0 0 1 |
00636   //
00637   // Notice this is a nrhs = 3 system.
00638   // Noteworthy: we do NOT ACTUALLY ALLOCATE space for the scalers... they
00639   // will be stored in the created identity matrix.
00640   // Let us first transpose subk (because of LAPACK):
00641
00642   int info{mtk::LAPACKAdapter::SolveDenseSystem(subk, iden)};
00643
00644   #if MTK_DEBUG_LEVEL > 0
00645   if (!info) {
00646     std::cout << "System successfully solved!" <<
00647       std::endl;
00648   } else {
00649     std::cerr << "Something went wrong solving system! info = " << info <<
00650       std::endl;
00651     std::cerr << "Exiting..." << std::endl;
00652     return false;
00653   }
00654   std::cout << std::endl;
00655   #endif
00656
00657   #if MTK_DEBUG_LEVEL > 0
00658   std::cout << "Computed scalers:" << std::endl;
00659   std::cout << iden << std::endl;
00660   #endif
00661
00662   // Multiply the two matrices to attain a scaled basis for null-space.
00663
00664   rat_basis_null_space_ = mtk::BLASAdapter::RealDenseMM(kk, iden);
00665
00666   #if MTK_DEBUG_LEVEL > 0
00667   std::cout << "Rational basis for the null-space:" << std::endl;
00668   std::cout << rat_basis_null_space_ << std::endl;
00669   #endif
00670
00671   // At this point, we have a rational basis for the null-space, with the
00672   // pattern we need! :)
00673
00674   delete [] gg;
00675   gg = nullptr;
00676
00677   return true;
00678 }
00679
00680 bool mtk::Grad1D::ComputePreliminaryApproximations() {
00681
00683
00684   mtk::Real *gg{}; // Generator vector for the first approximation.
00685
00686   try {
00687     gg = new mtk::Real[num_bndy_coeffs_];
00688   } catch (std::bad_alloc &memory_allocation_exception) {
00689     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00690       std::endl;
00691     std::cerr << memory_allocation_exception.what() << std::endl;
00692   }
00693   memset(gg, mtk::kZero, sizeof(gg[0])*num_bndy_coeffs_);
00694
00695   #ifdef MTK_PRECISION_DOUBLE
00696   gg[1] = 1.0/2.0;
00697   #else
00698   gg[1] = 1.0f/2.0f;
```

```
00699   #endif
00700   for (auto ii = 2; ii < num_bndy_coeffs_; ++ii) {
00701     gg[ii] = gg[ii - 1] + mtk::kOne;
00702   }
00703
00704   #if MTK_DEBUG_LEVEL > 0
00705   std::cout << "gg0 =" << std::endl;
00706   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00707     std::cout << std::setw(12) << gg[ii];
00708   }
00709   std::cout << std::endl << std::endl;
00710   #endif
00711
00712   // Allocate 2D array to store the collection of preliminary approximations.
00713   try {
00714     prem_apps_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
00715   } catch (std::bad_alloc &memory_allocation_exception) {
00716     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00717 std::endl;
00718     std::cerr << memory_allocation_exception.what() << std::endl;
00719   }
00720   memset(prem_apps_,
00721          mtk::kZero,
00722          sizeof(prem_apps_[0])*num_bndy_coeffs_*num_bndy_approxs_);
00723
00725
00726   for (auto ll = 0; ll < num_bndy_approxs_; ++ll) {
00727
00728     // Re-check new generator vector for every iteration except for the first.
00729     #if MTK_DEBUG_LEVEL > 0
00730     if (ll > 0) {
00731       std::cout << "gg" << ll << " =" << std::endl;
00732       for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00733         std::cout << std::setw(12) << gg[ii];
00734       }
00735       std::cout << std::endl << std::endl;
00736     }
00737     #endif
00738
00740
00741     bool transpose{false};
00742
00743     mtk::DenseMatrix aa(gg,
00744                         num_bndy_coeffs_, order_accuracy_ + 1,
00745                         transpose);
00746
00747     #if MTK_DEBUG_LEVEL > 0
00748     std::cout << "aa_" << ll << " =" << std::endl;
00749     std::cout << aa << std::endl;
00750     #endif
00751
00753
00754     mtk::Real *ob{};
00755
00756     auto ob_ld = num_bndy_coeffs_;
00757
00758     try {
00759       ob = new mtk::Real[ob_ld];
00760     } catch (std::bad_alloc &memory_allocation_exception) {
00761       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00762         std::endl;
00763       std::cerr << memory_allocation_exception.what() << std::endl;
00764     }
00765     memset(ob, mtk::kZero, sizeof(ob[0])*ob_ld);
00766
00767     ob[1] = mtk::kOne;
00768
00769     #if MTK_DEBUG_LEVEL > 0
00770     std::cout << "ob = " << std::endl << std::endl;
00771     for (auto ii = 0; ii < ob_ld; ++ii) {
00772       std::cout << std::setw(12) << ob[ii] << std::endl;
00773     }
00774     std::cout << std::endl;
00775     #endif
00776
00778
00779     // However, this is an under-determined system of equations. So we can not
00780     // use the same LAPACK routine (dgesv_). We will instead use dgels_, through
00781     // our LAPACKAdapter class.
00782
00783     int info_{
```

```
00784       mtk::LAPACKAdapter::SolveRectangularDenseSystem(aa, ob
      , ob_ld)};
00785
00786     #if MTK_DEBUG_LEVEL > 0
00787     if (!info_) {
00788       std::cout << "System successfully solved!" << std::endl << std::endl;
00789     } else {
00790       std::cerr << "Error solving system! info = " << info_ << std::endl;
00791     }
00792     #endif
00793
00794     #if MTK_DEBUG_LEVEL > 0
00795     std::cout << "ob =" << std::endl;
00796     for (auto ii = 0; ii < ob_ld; ++ii) {
00797       std::cout << std::setw(12) << ob[ii] << std::endl;
00798     }
00799     std::cout << std::endl;
00800     #endif
00801
00803
00804     // This implies a DAXPY operation. However, we must construct the arguments
00805     // for this operation.
00806
00808     // Save them into the ob_bottom array:
00809
00810     Real *ob_bottom{}; // Bottom part of the attained kernel used to scale it.
00811
00812     try {
00813       ob_bottom = new mtk::Real[dim_null_];
00814     } catch (std::bad_alloc &memory_allocation_exception) {
00815       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00816         std::endl;
00817       std::cerr << memory_allocation_exception.what() << std::endl;
00818     }
00819     memset(ob_bottom, mtk::kZero, sizeof(ob_bottom[0])*dim_null_);
00820
00821     for (auto ii = 0; ii < dim_null_; ++ii) {
00822       ob_bottom[(dim_null_ - 1) - ii] = ob[num_bndy_coeffs_ - ii - 1];
00823     }
00824
00825     #if MTK_DEBUG_LEVEL > 0
00826     std::cout << "ob_bottom =" << std::endl;
00827     for (auto ii = 0; ii < dim_null_; ++ii) {
00828       std::cout << std::setw(12) << ob_bottom[ii] << std::endl;
00829     }
00830     std::cout << std::endl;
00831     #endif
00832
00834
00835     // We must computed an scaled ob, sob, using the scaled null-space in
00836     // rat_basis_null_space_.
00837     // Such operation is: sob = ob - rat_basis_null_space_*ob_bottom
00838     // or:                ob = -1.0*rat_basis_null_space_*ob_bottom + 1.0*ob
00839     // thus:               Y =    a*A    *x         +   b*Y (DAXPY).
00840
00841     #if MTK_DEBUG_LEVEL > 0
00842     std::cout << "Rational basis for the null-space:" << std::endl;
00843     std::cout << rat_basis_null_space_ << std::endl;
00844     #endif
00845
00846     mtk::Real alpha{-mtk::kOne};
00847     mtk::Real beta{mtk::kOne};
00848
00849     mtk::BLASAdapter::RealDenseMV(alpha, rat_basis_null_space_,
00850                                   ob_bottom, beta, ob);
00851
00852     #if MTK_DEBUG_LEVEL > 0
00853     std::cout << "scaled ob:" << std::endl;
00854     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00855       std::cout << std::setw(12) << ob[ii] << std::endl;
00856     }
00857     std::cout << std::endl;
00858     #endif
00859
00860     // We save the recently scaled solution, into an array containing these.
00861     // We can NOT start building the pi matrix, simply because I want that part
00862     // to be separated since its construction depends on the algorithm we want
00863     // to implement.
00864
00865     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00866       prem_apps_[ii*num_bndy_approxs_ + ll] = ob[ii];
```

```
00867     }
00868
00869     // After the first iteration, simply shift the entries of the last
00870     // generator vector used:
00871     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00872       gg[ii]--;
00873     }
00874
00875     // Garbage collection for this loop:
00876     delete[] ob;
00877     ob = nullptr;
00878
00879     delete[] ob_bottom;
00880     ob_bottom = nullptr;
00881   } // End of: for (ll = 0; ll < dim_null; ll++);
00882
00883   #if MTK_DEBUG_LEVEL > 0
00884   std::cout << "Matrix post-scaled preliminary apps: " << std::endl;
00885   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00886     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
00887       std::cout << std::setw(12) << prem_apps_[ii*num_bndy_approxs_ + jj];
00888     }
00889     std::cout << std::endl;
00890   }
00891   std::cout << std::endl;
00892   #endif
00893
00894   delete[] gg;
00895   gg = nullptr;
00896
00897   return true;
00898 }
00899
00900 bool mtk::Grad1D::ComputeWeights() {
00901
00902   // Matrix to copmpute the weights as in the CRSA.
00903   mtk::DenseMatrix pi(num_bndy_coeffs_, num_bndy_coeffs_ - 1);
00904
00906
00907   // Assemble the pi matrix using:
00908   // 1. The collection of scaled preliminary approximations.
00909   // 2. The collection of coefficients approximating at the interior.
00910   // 3. The scaled basis for the null-space.
00911
00912   // 1.1. Process array of scaled preliminary approximations.
00913
00914   // These are queued in scaled_solutions. Each one of these, will be a column
00915   // of the pi matrix:
00916   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00917     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
00918       pi.data()[ii*(2*(num_bndy_approxs_ - 1) + (order_accuracy_/2 + 1)) + jj] =
00919         prem_apps_[ii*num_bndy_approxs_ + jj];
00920     }
00921   }
00922
00923   // 1.2. Add columns from known stencil approximating at the interior.
00924
00925   // However, these must be padded by zeros, according to their position in the
00926   // final pi matrix:
00927   auto mm = 1;
00928   for (auto jj = num_bndy_approxs_; jj < order_accuracy_; ++jj) {
00929     for (auto ii = 0; ii < order_accuracy_; ++ii) {
00930       auto de = (ii + mm)*(2*(num_bndy_approxs_ - 1) +
00931         (order_accuracy_/2 + 1)) + jj;
00932       pi.data()[de] = coeffs_interior_[ii];
00933     }
00934     ++mm;
00935   }
00936
00937   rat_basis_null_space_.OrderColMajor();
00938
00939   #if MTK_DEBUG_LEVEL > 0
00940   std::cout << "Rational basis for the null-space (col. major):" << std::endl;
00941   std::cout << rat_basis_null_space_ << std::endl;
00942   #endif
00943
00944   // 1.3. Add final set of columns: rational basis for null-space.
00945   for (auto jj = dim_null_ + (order_accuracy_/2 + 1);
00946        jj < num_bndy_coeffs_ - 1; ++jj) {
00947     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
00948       auto og =
```

```
00949         (jj - (dim_null_ + (order_accuracy_/2 + 1)))*num_bndy_coeffs_ + ii;
00950       auto de = ii*(2*dim_null_ + (order_accuracy_/2 + 1)) + jj;
00951       pi.data()[de] = rat_basis_null_space_.data()[og];
00952     }
00953   }
00954
00955   #if MTK_DEBUG_LEVEL >0
00956   std::cout << "coeffs_interior_ =" << std::endl;
00957   for (auto ii = 0; ii < order_accuracy_; ++ii) {
00958     std::cout << std::setw(12) << coeffs_interior_[ii];
00959   }
00960   std::cout << std::endl << std::endl;
00961   #endif
00962
00963   #if MTK_DEBUG_LEVEL >0
00964   std::cout << "Constructed pi matrix for CRS Algorithm: " << std::endl;
00965   std::cout << pi << std::endl;
00966   #endif
00967
00969
00970   // This imposes the mimetic condition.
00971
00972   mtk::Real *hh{};  // Right-hand side to compute weights in the C{R,B}SA.
00973
00974   try {
00975     hh = new mtk::Real[num_bndy_coeffs_];
00976   } catch (std::bad_alloc &memory_allocation_exception) {
00977     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00978       std::endl;
00979     std::cerr << memory_allocation_exception.what() << std::endl;
00980   }
00981   memset(hh, mtk::kZero, sizeof(hh[0])*num_bndy_coeffs_);
00982
00983   hh[0] = -mtk::kOne;
00984   for (auto ii = (order_accuracy_/2 + 2 - 1); ii < num_bndy_coeffs_; ++ii) {
00985     auto aux_xx = mtk::kZero;
00986     for (auto jj = 0; jj < ((ii - (order_accuracy_/2 - 1)) - 1); ++jj) {
00987       aux_xx += coeffs_interior_[jj];
00988     }
00989     hh[ii] = -mtk::kOne*aux_xx;
00990   }
00991
00993
00994   // That is, we construct a system, to solve for the weights.
00995
00996   // Once again we face the challenge of solving with LAPACK. However, for the
00997   // CRSA, this matrix PI is over-determined, since it has more rows than
00998   // unknowns. However, according to the theory, the solution to this system is
00999   // unique. We will use dgels_.
01000
01001   try {
01002     weights_cbs_ = new mtk::Real[num_bndy_coeffs_];
01003   } catch (std::bad_alloc &memory_allocation_exception) {
01004     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01005       std::endl;
01006     std::cerr << memory_allocation_exception.what() << std::endl;
01007   }
01008   memset(weights_cbs_, mtk::kZero, sizeof(weights_cbs_[0])*num_bndy_coeffs_);
01009
01010   int weights_ld{pi.num_cols() + 1};
01011
01012   // Preserve hh.
01013   std::copy(hh, hh + weights_ld, weights_cbs_);
01014
01015   pi.Transpose();
01016
01017   int info{
01018     mtk::LAPACKAdapter::SolveRectangularDenseSystem(pi,
01019                                                     weights_cbs_, weights_ld)
01020   };
01021
01022   #if MTK_DEBUG_LEVEL > 0
01023   if (!info) {
01024     std::cout << "System successfully solved!" << std::endl << std::endl;
01025   } else {
01026     std::cerr << "Error solving system! info = " << info << std::endl;
01027   }
01028   #endif
01029
01030   #if MTK_DEBUG_LEVEL > 0
01031   std::cout << "hh =" << std::endl;
```

```
01032   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01033     std::cout << std::setw(11) << hh[ii] << std::endl;
01034   }
01035   std::cout << std::endl;
01036   #endif
01037
01038   // Preserve the original weights for research.
01039
01040   try {
01041     weights_crs_ = new mtk::Real[num_bndy_coeffs_];
01042   } catch (std::bad_alloc &memory_allocation_exception) {
01043     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01044       std::endl;
01045     std::cerr << memory_allocation_exception.what() << std::endl;
01046   }
01047   memset(weights_crs_, mtk::kZero, sizeof(weights_crs_[0])*num_bndy_coeffs_);
01048
01049   std::copy(weights_cbs_, weights_cbs_ + (weights_ld - 1), weights_crs_);
01050
01051   #if MTK_DEBUG_LEVEL > 0
01052   std::cout << "weights_CRSA + lambda =" << std::endl;
01053   for (auto ii = 0; ii < weights_ld - 1; ++ii) {
01054     std::cout << std::setw(12) << weights_crs_[ii] << std::endl;
01055   }
01056   std::cout << std::endl;
01057   #endif
01058
01060   if (order_accuracy_ >= mtk::kCriticalOrderAccuracyGrad) {
01061
01062     int minrow_{std::numeric_limits<int>::infinity()};
01063
01064     mtk::Real norm{mtk::BLASAdapter::RealNRM2(weights_cbs_,
      order_accuracy_)};
01065     mtk::Real minnorm{std::numeric_limits<mtk::Real>::infinity()};
01066
01068
01069     mtk::DenseMatrix phi(order_accuracy_ + 1, order_accuracy_);
01070
01071     // 6.1. Insert preliminary approximations to first set of columns.
01072
01073     for (auto ii = 0; ii < order_accuracy_ + 1; ++ii) {
01074       for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01075         phi.data()[ii*(order_accuracy_) + jj] =
01076           prem_apps_[ii*num_bndy_approxs_ + jj];
01077       }
01078     }
01079
01080     // 6.2. Skip a column and negate preliminary approximations.
01081
01082     for (auto jj = 0; jj < order_accuracy_ + 1; jj++) {
01083       for (auto ii = 1; ii < num_bndy_approxs_; ii++) {
01084         auto de = (ii+ order_accuracy_ - num_bndy_approxs_+ jj*order_accuracy_);
01085         auto og = (num_bndy_approxs_ - ii + (jj)*num_bndy_approxs_);
01086         phi.data()[de] = -prem_apps_[og];
01087       }
01088     }
01089
01090     // 6.3. Flip negative columns up-down.
01091
01092     for (auto ii = 0; ii < order_accuracy_/2; ii++) {
01093       for (auto jj = num_bndy_approxs_ + 1; jj < order_accuracy_; jj++) {
01094         auto aux = phi.data()[ii*order_accuracy_ + jj];
01095         phi.data()[ii*order_accuracy_ + jj] =
01096           phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj];
01097         phi.data()[(order_accuracy_ - ii)*order_accuracy_ + jj] = aux;
01098       }
01099     }
01100
01101     // 6.4. Insert stencil.
01102
01103     auto mm = 0;
01104     for (auto jj = num_bndy_approxs_; jj < num_bndy_approxs_ +  1; jj++) {
01105       for (auto ii = 0; ii < order_accuracy_ + 1; ii++) {
01106         if (ii == 0) {
01107           phi.data()[jj] = 0.0;
01108         } else {
01109           phi.data()[(ii + mm)*order_accuracy_ + jj] = coeffs_interior_[ii - 1];
01110         }
01111       }
01112       mm++;
01113     }
```

```
01114
01115     #if MTK_DEBUG_LEVEL > 0
01116     std::cout << "phi =" << std::endl;
01117     std::cout << phi << std::endl;
01118     #endif
01119
01121
01122     mtk::Real *lamed{};  // Used to build big lambda.
01123
01124     try {
01125       lamed = new mtk::Real[num_bndy_approxs_ - 1];
01126     } catch (std::bad_alloc &memory_allocation_exception) {
01127       std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01128         std::endl;
01129       std::cerr << memory_allocation_exception.what() << std::endl;
01130     }
01131     memset(lamed, mtk::kZero, sizeof(lamed[0])*(num_bndy_approxs_ - 1));
01132
01133     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01134       lamed[ii] = hh[ii + order_accuracy_ + 1] ;
01135     }
01136
01137     #if MTK_DEBUG_LEVEL > 0
01138     std::cout << "lamed =" << std::endl;
01139     for (auto ii = 0; ii < num_bndy_approxs_ - 1; ++ii) {
01140       std::cout << std::setw(12) << lamed[ii] << std::endl;
01141     }
01142     std::cout << std::endl;
01143     #endif
01144
01145     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01146       mtk::Real temp = mtk::kZero;
01147       for(auto jj = 0; jj < num_bndy_approxs_ - 1; ++jj) {
01148         temp = temp +
01149           lamed[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01150       }
01151       hh[ii] = hh[ii] - temp;
01152     }
01153
01154     #if MTK_DEBUG_LEVEL > 0
01155     std::cout << "big_lambda =" << std::endl;
01156     for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01157       std::cout << std::setw(12) << hh[ii] << std::endl;
01158     }
01159     std::cout << std::endl;
01160     #endif
01161
01163
01164     int copy_result{};  // Should I replace the solution... not for now.
01165
01166     mtk::Real normerr_; // Norm of the error for the solution on each row.
01167
01168     for(auto row_= 0; row_ < order_accuracy_ + 1; ++row_) {
01169       normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01170                                                           order_accuracy_ + 1,
01171                                                           order_accuracy_,
01172                                                           order_accuracy_,
01173                                                           hh,
01174                                                           weights_cbs_,
01175                                                           row_,
01176                                                           mimetic_threshold_,
01177                                                           copy_result);
01178       mtk::Real aux{normerr_/norm};
01179
01180       #if MTK_DEBUG_LEVEL>0
01181       std::cout << "Relative norm: " << aux << " " << std::endl;
01182       std::cout << std::endl;
01183       #endif
01184
01185       if (aux < minnorm) {
01186         minnorm = aux;
01187         minrow_= row_;
01188       }
01189     }
01190
01191     #if MTK_DEBUG_LEVEL > 0
01192     std::cout << "weights_CBSA + lambda (after brute force search):" <<
01193       std::endl;
01194     for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01195       std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
```

```
01196     }
01197     std::cout << std::endl;
01198     #endif
01199
01201
01202     // After we know which row yields the smallest relative norm that row is
01203     // chosen to be the objective function and the result of the optimizer is
01204     // chosen to be the new weights_.
01205
01206     #if MTK_DEBUG_LEVEL > 0
01207     std::cout << "Minimum Relative Norm " << minnorm << " found at row " <<
01208       minrow_ + 1 << std::endl;
01209     std::cout << std::endl;
01210     #endif
01211
01212     copy_result = 1;
01213     normerr_ = mtk::GLPKAdapter::SolveSimplexAndCompare(phi.
      data(),
01214                                                         order_accuracy_ + 1,
01215                                                         order_accuracy_,
01216                                                         order_accuracy_,
01217                                                         hh,
01218                                                         weights_cbs_,
01219                                                         minrow_,
01220                                                         mimetic_threshold_,
01221                                                         copy_result);
01222     mtk::Real aux_{normerr_/norm};
01223     #if MTK_DEBUG_LEVEL > 0
01224     std::cout << "Relative norm: " << aux_ << std::endl;
01225     std::cout << std::endl;
01226     #endif
01227
01228     delete [] lamed;
01229     lamed = nullptr;
01230   }
01231
01232   delete [] hh;
01233   hh = nullptr;
01234
01235   return true;
01236 }
01237
01238 bool mtk::Grad1D::ComputeStencilBoundaryGrid(void) {
01239
01240   #if MTK_DEBUG_LEVEL > 0
01241   std::cout << "weights_* + lambda =" << std::endl;
01242   for (auto ii = 0; ii < num_bndy_coeffs_ - 1; ++ii) {
01243     std::cout << std::setw(12) << weights_cbs_[ii] << std::endl;
01244   }
01245   std::cout << std::endl;
01246   #endif
01247
01249
01250   mtk::Real *lambda{}; // Collection of bottom values from weights_.
01251
01252   try {
01253     lambda = new mtk::Real[dim_null_];
01254   } catch (std::bad_alloc &memory_allocation_exception) {
01255     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01256       std::endl;
01257     std::cerr << memory_allocation_exception.what() << std::endl;
01258   }
01259   memset(lambda, mtk::kZero, sizeof(lambda[0])*dim_null_);
01260
01261   for (auto ii = 0; ii < dim_null_; ++ii) {
01262     lambda[ii] = weights_cbs_[order_accuracy_ + ii];
01263   }
01264
01265   #if MTK_DEBUG_LEVEL > 0
01266   std::cout << "lambda =" << std::endl;
01267   for (auto ii = 0; ii < dim_null_; ++ii) {
01268     std::cout << std::setw(12) << lambda[ii] << std::endl;
01269   }
01270   std::cout << std::endl;
01271   #endif
01272
01274
01275   mtk::Real *alpha{}; // Collection of alpha values.
01276
01277   try {
01278     alpha = new mtk::Real[dim_null_];
```

```
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(alpha, mtk::kZero, sizeof(alpha[0])*dim_null_);
01285
01286   for (auto ii = 0; ii < dim_null_; ++ii) {
01287     alpha[ii] = lambda[ii]/weights_cbs_[ii] ;
01288   }
01289
01290   #if MTK_DEBUG_LEVEL > 0
01291   std::cout << "alpha =" << std::endl;
01292   for (auto ii = 0; ii < dim_null_; ++ii) {
01293     std::cout << std::setw(12) << alpha[ii] << std::endl;
01294   }
01295   std::cout << std::endl;
01296   #endif
01297
01299
01300   try {
01301     mim_bndy_ = new mtk::Real[num_bndy_coeffs_*num_bndy_approxs_];
01302   } catch (std::bad_alloc &memory_allocation_exception) {
01303     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01304       std::endl;
01305     std::cerr << memory_allocation_exception.what() << std::endl;
01306   }
01307   memset(mim_bndy_,
01308          mtk::kZero,
01309          sizeof(mim_bndy_[0])*num_bndy_coeffs_*num_bndy_approxs_);
01310
01311   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01312     for (auto jj = 0; jj < (num_bndy_approxs_ - 1); ++jj) {
01313       mim_bndy_[ii*num_bndy_approxs_ + jj] =
01314         prem_apps_[ii*num_bndy_approxs_ + jj] +
01315         alpha[jj]*rat_basis_null_space_.data()[jj*num_bndy_coeffs_ + ii];
01316     }
01317   }
01318
01319   for(auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01320     mim_bndy_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)] =
01321       prem_apps_[ii*num_bndy_approxs_ + (num_bndy_approxs_ - 1)];
01322   }
01323
01324   #if MTK_DEBUG_LEVEL > 0
01325   std::cout << "Collection of mimetic approximations:" << std::endl;
01326   for (auto ii = 0; ii < num_bndy_coeffs_; ++ii) {
01327     for (auto jj = 0; jj < num_bndy_approxs_; ++jj) {
01328       std::cout << std::setw(13) << mim_bndy_[ii*num_bndy_approxs_ + jj];
01329     }
01330     std::cout << std::endl;
01331   }
01332   std::cout << std::endl;
01333   #endif
01334
01335   delete[] lambda;
01336   lambda = nullptr;
01337
01338   delete[] alpha;
01339   alpha = nullptr;
01340
01341   return true;
01342 }
01343
01344 bool mtk::Grad1D::AssembleOperator(void) {
01345
01346   // The output array will have this form:
01347   // 1. The first entry of the array will contain the used order kk.
01348   // 2. The second entry of the array will contain the collection of
01349   // approximating coefficients for the interior of the grid.
01350   // 3. The third entry will contain a collection of weights.
01351   // 4. The next dim_null - 1 entries will contain the collections of
01352   // approximating coefficients for the west boundary of the grid.
01353
01354   gradient_length_ = 1 + order_accuracy_ + order_accuracy_ +
01355     num_bndy_approxs_*num_bndy_coeffs_;
01356
01357   #if MTK_DEBUG_LEVEL > 0
01358   std::cout << "gradient_length_ = " << gradient_length_ << std::endl;
01359   #endif
01360
```

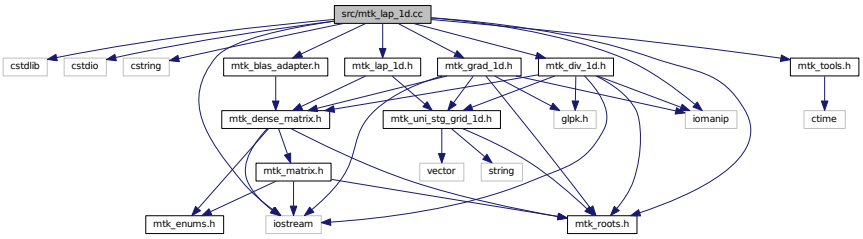
```
01361   try {
01362     gradient_ = new mtk::Real[gradient_length_];
01363   } catch (std::bad_alloc &memory_allocation_exception) {
01364     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
01365       std::endl;
01366     std::cerr << memory_allocation_exception.what() << std::endl;
01367   }
01368   memset(gradient_, mtk::kZero, sizeof(gradient_[0])*gradient_length_);
01369
01371
01372   gradient_[0] = order_accuracy_;
01373
01376
01377   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01378     gradient_[ii + 1] = coeffs_interior_[ii];
01379   }
01380
01382
01383   for (auto ii = 0; ii < order_accuracy_; ++ii) {
01384     gradient_[(order_accuracy_ + 1) + ii] = weights_cbs_[ii];
01385   }
01386
01389
01390   int offset{2*order_accuracy_ + 1};
01391
01392   int aux {}; // Auxiliary variable.
01393
01394   if (order_accuracy_ > mtk::kDefaultOrderAccuracy) {
01395     for (auto ii = 0; ii < num_bndy_approxs_ ; ii++) {
01396       for (auto jj = 0; jj < num_bndy_coeffs_; jj++) {
01397         gradient_[offset + aux] = mim_bndy_[jj*num_bndy_approxs_ + ii];
01398         aux++;
01399       }
01400     }
01401   } else {
01402     gradient_[offset + 0] = prem_apps_[0];
01403     gradient_[offset + 1] = prem_apps_[1];
01404     gradient_[offset + 2] = prem_apps_[2];
01405   }
01406
01407   #if MTK_DEBUG_LEVEL > 0
01408   std::cout << "1D " << order_accuracy_ << "-order grad built!" << std::endl;
01409   std::cout << std::endl;
01410   #endif
01411
01412   return true;
01413 }
```

17.43 src/mtk_lap_1d.cc File Reference

Includes the implementation of the class Lap1D.

```
#include <cstdlib>
#include <cstdio>
#include <cstring>
#include <iostream>
#include <iomanip>
#include "mtk_roots.h"
#include "mtk_tools.h"
#include "mtk_blas_adapter.h"
#include "mtk_grad_1d.h"
#include "mtk_div_1d.h"
#include "mtk_lap_1d.h"
```

Include dependency graph for mtk_lap_1d.cc:



Namespaces

- mtk

  Mimetic Methods Toolkit namespace.

Functions

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

17.43.1 Detailed Description

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

Author

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Definition in file mtk_lap_1d.cc.

17.44 mtk_lap_1d.cc

```
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00021
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00024
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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
00076
00077   stream << "laplacian_[0] = " << in.laplacian_[0] << std::endl << std::endl;
00078
00080
00081   stream << "laplacian_[1:" << 2*in.order_accuracy_ - 1 << "] = " <<
00082     std::endl << std::endl;
00083   for (auto ii = 1; ii <= (2*in.order_accuracy_ - 1); ++ii) {
00084     stream << std::setw(13) << in.laplacian_[ii] << " ";
00085   }
00086   stream << std::endl << std::endl;
00087
00089
00090   auto offset = 1 + (2*in.order_accuracy_ - 1);
00091
00092   stream << "laplacian_[" << offset << ":" << offset +
00093     (in.order_accuracy_ - 1)*(2*in.order_accuracy_) - 1 << "] = " <<
00094     std::endl << std::endl;
00095
00096   for (auto ii = 0; ii < in.order_accuracy_ - 1; ++ii) {
00097     for (auto jj = 0; jj < 2*in.order_accuracy_; ++jj) {
00098       stream << std::setw(13) <<
00099         in.laplacian_[offset + ii*(2*in.order_accuracy_) + jj];
00100     }
00101     stream << std::endl;
00102   }
00103
00104   return stream;
00105 }
00106 }
00107
00108 mtk::Lap1D::Lap1D():
00109   order_accuracy_(mtk::kDefaultOrderAccuracy),
00110   laplacian_length_(),
00111   mimetic_threshold_(mtk::kDefaultMimeticThreshold) {}
00112
00113 mtk::Lap1D::~Lap1D() {
00114
00115   delete [] laplacian_;
```

```
00116   laplacian_ = nullptr;
00117 }
00118
00119 bool mtk::Lap1D::ConstructLap1D(int order_accuracy,
00120                                 mtk::Real mimetic_threshold) {
00121
00122   #if MTK_DEBUG_LEVEL > 0
00123   mtk::Tools::Prevent(order_accuracy < 2, __FILE__, __LINE__, __func__);
00124   mtk::Tools::Prevent((order_accuracy%2) != 0, __FILE__, __LINE__, __func__);
00125   mtk::Tools::Prevent(mimetic_threshold <= mtk::kZero,
00126                       __FILE__, __LINE__, __func__);
00127
00128   if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00129     std::cout << "WARNING: Numerical accuracy is high." << std::endl;
00130   }
00131
00132   std::cout << "order_accuracy_ = " << order_accuracy << std::endl;
00133   std::cout << "mimetic_threshold_ = " << mimetic_threshold << std::endl;
00134   #endif
00135
00136   order_accuracy_ = order_accuracy;
00137   mimetic_threshold_ = mimetic_threshold;
00138
00140
00141   mtk::Grad1D grad; // Mimetic gradient.
00142
00143   bool info = grad.ConstructGrad1D(order_accuracy_, mimetic_threshold_);
00144
00145   if (!info) {
00146     std::cerr << "Mimetic grad could not be built." << std::endl;
00147     return false;
00148   }
00149
00151
00152   mtk::Div1D div; // Mimetic divergence.
00153
00154   info = div.ConstructDiv1D(order_accuracy_, mimetic_threshold_);
00155
00156   if (!info) {
00157     std::cerr << "Mimetic div could not be built." << std::endl;
00158     return false;
00159   }
00160
00162
00163   // Since these are mimetic operator, we must multiply the matrices arising
00164   // from both the divergence and the Laplacian, in order to get the
00165   // approximating coefficients for the Laplacian operator.
00166
00167   // However, we must choose a grid that implied a step size of 1, so to get
00168   // the approximating coefficients, without being affected from the
00169   // normalization with respect to the grid.
00170
00171   // Also, the grid must be of the minimum size to support the requested order
00172   // of accuracy. We must please the divergence.
00173
00174   mtk::UniStgGrid1D aux(mtk::kZero,
00175                         (mtk::Real) 3*order_accuracy_ - 1,
00176                         3*order_accuracy_ - 1);
00177
00178   #if MTK_DEBUG_LEVEL > 0
00179   std::cout << "aux =" << std::endl;
00180   std::cout << aux << std::endl;
00181   std::cout <<"aux.delta_x() = " << aux.delta_x() << std::endl;
00182   std::cout << std::endl;
00183   #endif
00184
00185   mtk::DenseMatrix grad_m(grad.ReturnAsDenseMatrix(aux));
00186
00187   #if MTK_DEBUG_LEVEL > 0
00188   std::cout << "grad_m =" << std::endl;
00189   std::cout << grad_m << std::endl;
00190   #endif
00191
00192   mtk::DenseMatrix div_m(div.ReturnAsDenseMatrix(aux));
00193
00194   #if MTK_DEBUG_LEVEL > 0
00195   std::cout << "div_m =" << std::endl;
00196   std::cout << div_m << std::endl;
00197   #endif
00198
00202
```

```
00203   mtk::DenseMatrix lap; // Laplacian matrix to hold to computed coefficients.
00204
00205   lap = mtk::BLASAdapter::RealDenseMM(div_m, grad_m);
00206
00207   #if MTK_DEBUG_LEVEL > 0
00208   std::cout << "lap =" << std::endl;
00209   std::cout << lap << std::endl;
00210   #endif
00211
00213
00215
00216   // The output array will have this form:
00217   // 1. The first entry of the array will contain the used order kk.
00218   // 2. The second entry of the array will contain the collection of
00219   // approximating coefficients for the interior of the grid.
00220   // 3. The next entries will contain the collections of approximating
00221   // coefficients for the west boundary of the grid.
00222
00223   laplacian_length_ = 1 + (2*order_accuracy_ - 1) +
00224     (order_accuracy_ - 1)*(2*order_accuracy_);
00225
00226   #if MTK_DEBUG_LEVEL > 0
00227   std::cout << "laplacian_length_ = " << laplacian_length_ << std::endl;
00228   std::cout << std::endl;
00229   #endif
00230
00231   try {
00232     laplacian_ = new mtk::Real[laplacian_length_];
00233   } catch (std::bad_alloc &memory_allocation_exception) {
00234     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00235       std::endl;
00236     std::cerr << memory_allocation_exception.what() << std::endl;
00237   }
00238   memset(laplacian_, mtk::kZero, sizeof(laplacian_[0])*laplacian_length_);
00239
00241
00242   laplacian_[0] = order_accuracy_;
00243
00246
00247   for (auto ii = 0; ii < 2*order_accuracy_ - 1; ++ii) {
00248     laplacian_[ii + 1] = lap.GetValue(1 + (order_accuracy_ - 1), ii + 1);
00249   }
00250
00252
00253   auto offset = 1 + (2*order_accuracy_ - 1);
00254
00255   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00256     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00257       laplacian_[offset + ii*(2*order_accuracy_) + jj] =
00258         lap.GetValue(1 + ii,jj);
00259     }
00260   }
00261
00262   return true;
00263 }
00264
00265 mtk::DenseMatrix mtk::Lap1D::ReturnAsDenseMatrix(const
      UniStgGrid1D &grid) {
00266
00267   int nn{grid.num_cells_x()};  // Number of cells on the grid.
00268
00269   #if MTK_DEBUG_LEVEL > 0
00270   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00271   mtk::Tools::Prevent(nn < 3*order_accuracy_ - 1, __FILE__, __LINE__, __func__);
00272   #endif
00273
00274   mtk::DenseMatrix lap(nn + 2, nn + 2); // Laplacian matrix to be returned.
00275
00276   mtk::Real idx{mtk::kOne/(grid.delta_x()*grid.delta_x())}; // Inverse of
       dx^2.
00277
00279
00280   auto offset = (1 + 2*order_accuracy_ - 1);
00281
00282   for (auto ii = 0; ii < order_accuracy_ - 1; ++ii) {
00283     for (auto jj = 0; jj < 2*order_accuracy_; ++jj) {
00284       lap.SetValue(1 + ii,
00285                    jj,
00286                    idx*laplacian_[offset + ii*2*order_accuracy_ + jj]);
00287     }
00288   }
```

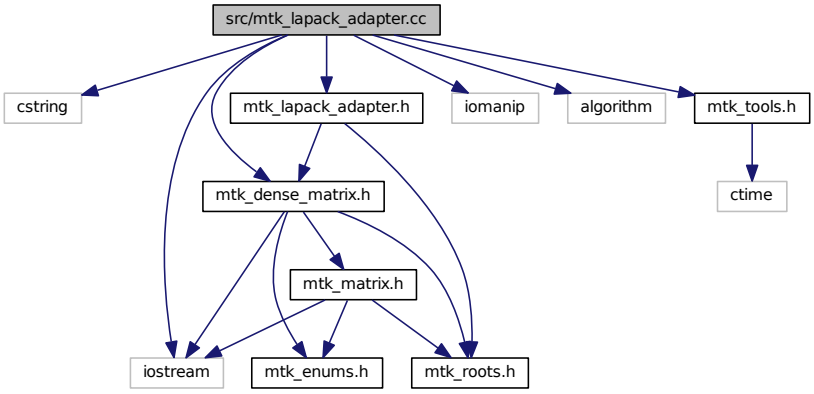
```
00289
00291
00292   offset = 1 + (order_accuracy_ - 1);
00293
00294   int kk{1};
00295   for (auto ii = order_accuracy_; ii <= nn - (order_accuracy_ - 1); ++ii) {
00296     int mm{1};
00297     for (auto jj = 0; jj < 2*order_accuracy_ - 1; ++jj) {
00298       lap.SetValue(ii, jj + kk, idx*laplacian_[mm]);
00299       mm = mm + 1;
00300     }
00301     kk = kk + 1;
00302   }
00303
00305
00306   offset = (1 + 2*order_accuracy_ - 1);
00307
00308   auto aux = order_accuracy_ + (nn - 2*(order_accuracy_ - 1));
00309
00310   auto ll = 1;
00311   auto rr = 1;
00312   for (auto ii = nn; ii > aux - 1; --ii) {
00313     auto cc = 0;
00314     for (auto jj = nn + 2 - 1; jj >= (nn + 2) - 2*order_accuracy_; --jj) {
00315       lap.SetValue(ii, jj, lap.GetValue(rr,cc));
00316       ++ll;
00317       ++cc;
00318     }
00319     rr++;
00320   }
00321
00328
00329   return lap;
00330 }
00331
00332 mtk::Real* mtk::Lap1D::Data(const UniStgGrid1D &grid) {
00333
00334   mtk::DenseMatrix tmp;
00335
00336   tmp = ReturnAsDenseMatrix(grid);
00337
00338   return tmp.data();
00339 }
```

17.45 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.

17.45.1 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** 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

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Definition in file mtk_lapack_adapter.cc.

17.46 mtk_lapack_adapter.cc

```
00001
00018 /*
00019 Copyright (C) 2015, Computational Science Research Center, San Diego State
00020 University. All rights reserved.
00021
00022 Redistribution and use in source and binary forms, with or without modification,
00023 are permitted provided that the following conditions are met:
00024
00025 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00026 and a copy of the modified files should be reported once modifications are
00027 completed. Documentation related to said modifications should be included.
00028
00029 2. Redistributions of source code must be done through direct
00030 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00031
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00057 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00058 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00059 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00060 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00061 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00062 */
00063
00064 #include <cstring>
00065
00066 #include <iostream>
00067 #include <iomanip>
00068
00069 #include <algorithm>
00070
00071 #include "mtk_tools.h"
00072 #include "mtk_dense_matrix.h"
00073 #include "mtk_lapack_adapter.h"
00074
00075 namespace mtk {
00076
00077 extern "C" {
00078
00079 #ifdef MTK_PRECISION_DOUBLE
00080
00099 void dgesv_(int* n,
00100             int* nrhs,
00101             Real* a,
00102             int* lda,
```

```
00103             int* ipiv,
00104             Real* b,
00105             int* ldb,
00106             int* info);
00107 #else
00108
00127 void sgesv_(int* n,
00128             int* nrhs,
00129             Real* a,
00130             int* lda,
00131             int* ipiv,
00132             Real* b,
00133             int* ldb,
00134             int* info);
00135 #endif
00136
00137 #ifdef MTK_PRECISION_DOUBLE
00138
00181 void dgels_(char* trans,
00182             int* m,
00183             int* n,
00184             int* nrhs,
00185             Real* a,
00186             int* lda,
00187             Real* b,
00188             int* ldb,
00189             Real* work,
00190             int* lwork,
00191             int* info);
00192 #else
00193
00236 void sgels_(char* trans,
00237             int* m,
00238             int* n,
00239             int* nrhs,
00240             Real* a,
00241             int* lda,
00242             Real* b,
00243             int* ldb,
00244             Real* work,
00245             int* lwork,
00246             int* info);
00247 #endif
00248
00249 #ifdef MTK_PRECISION_DOUBLE
00250
00279 void dgeqrf_(int *m,
00280              int *n,
00281              Real *a,
00282              int *lda,
00283              Real *tau,
00284              Real *work,
00285              int *lwork,
00286              int *info);
00287 #else
00288
00317 void sgeqrf_(int *m,
00318              int *n,
00319              Real *a,
00320              int *lda,
00321              Real *tau,
00322              Real *work,
00323              int *lwork,
00324              int *info);
00325 #endif
00326
00327 #ifdef MTK_PRECISION_DOUBLE
00328
00362 void dormqr_(char *side,
00363              char *trans,
00364              int *m,
00365              int *n,
00366              int *k,
00367              Real *a,
00368              int *lda,
00369              Real *tau,
00370              Real *c,
00371              int *ldc,
00372              Real *work,
00373              int *lwork,
00374              int *info);
```

```
00375 #else
00376
00410 void sormqr_(char *side,
00411              char *trans,
00412              int *m,
00413              int *n,
00414              int *k,
00415              Real *a,
00416              int *lda,
00417              Real *tau,
00418              Real *c,
00419              int *ldc,
00420              Real *work,
00421              int *lwork,
00422              int *info);
00423 #endif
00424 }
00425 }
00426
00427 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00428                                          mtk::Real *rhs) {
00429
00430
00431   #if MTK_DEBUG_LEVEL > 0
00432   mtk::Tools::Prevent(rhs == nullptr, __FILE__, __LINE__, __func__);
00433   #endif
00434
00435   int *ipiv{};                // Array for pivoting information.
00436   int nrhs{1};                // Number of right-hand sides.
00437   int info{};                 // Status of the solution.
00438   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00439
00440   try {
00441     ipiv = new int[mm_rank];
00442   } catch (std::bad_alloc &memory_allocation_exception) {
00443     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00444       std::endl;
00445     std::cerr << memory_allocation_exception.what() << std::endl;
00446   }
00447   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00448
00449   int ldbb = mm_rank;
00450   int mm_ld = mm_rank;
00451
00452   #ifdef MTK_PRECISION_DOUBLE
00453   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00454   #else
00455   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, rhs, &ldbb, &info);
00456   #endif
00457
00458   delete [] ipiv;
00459
00460   return info;
00461 }
00462
00463 int mtk::LAPACKAdapter::SolveDenseSystem(
      mtk::DenseMatrix &mm,
00464                                          mtk::DenseMatrix &bb) {
00465
00466   int nrhs{bb.num_rows()};  // Number of right-hand sides.
00467
00468   #if MTK_DEBUG_LEVEL > 0
00469   mtk::Tools::Prevent(nrhs <= 0, __FILE__, __LINE__, __func__);
00470   #endif
00471
00472   int *ipiv{};                // Array for pivoting information.
00473   int info{};                 // Status of the solution.
00474   int mm_rank{mm.num_rows()}; // Rank of the matrix.
00475
00476   try {
00477     ipiv = new int[mm_rank];
00478   } catch (std::bad_alloc &memory_allocation_exception) {
00479     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00480       std::endl;
00481     std::cerr << memory_allocation_exception.what() << std::endl;
00482   }
00483   memset(ipiv, 0, sizeof(ipiv[0])*mm_rank);
00484
00485   int ldbb = mm_rank;
00486   int mm_ld = mm_rank;
```

```
00487
00488   #ifdef MTK_PRECISION_DOUBLE
00489   dgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00490   #else
00491   fgesv_(&mm_rank, &nrhs, mm.data(), &mm_ld, ipiv, bb.data(), &ldbb, &info);
00492   #endif
00493
00494   delete [] ipiv;
00495
00496   // After output, the data in the matrix will be column-major ordered.
00497
00498   bb.SetOrdering(mtk::COL_MAJOR);
00499
00500   #if MTK_DEBUG_LEVEL > 0
00501   std::cout << "bb_col_maj_ord =" << std::endl;
00502   std::cout << bb << std::endl;
00503   #endif
00504
00505   bb.OrderRowMajor();
00506
00507   #if MTK_DEBUG_LEVEL > 0
00508   std::cout << "bb_row_maj_ord =" << std::endl;
00509   std::cout << bb << std::endl;
00510   #endif
00511
00512   return info;
00513 }
00514
00515 mtk::DenseMatrix mtk::LAPACKAdapter::QRFactorDenseMatrix
      (mtk::DenseMatrix &aa) {
00516
00517   mtk::Real *work{}; // Working array.
00518   mtk::Real *tau{};  // Array for the Householder scalars.
00519
00520   // Prepare to factorize: allocate and inquire for the value of lwork.
00521   try {
00522     work = new mtk::Real[1];
00523   } catch (std::bad_alloc &memory_allocation_exception) {
00524     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00525       std::endl;
00526     std::cerr << memory_allocation_exception.what() << std::endl;
00527   }
00528   memset(work, mtk::kZero, sizeof(aa.data()[0])*1);
00529
00530   int lwork{-1};
00531   int info{};
00532
00533   int aa_num_cols = aa.num_cols();
00534   int aaT_num_rows = aa.num_cols();
00535   int aaT_num_cols = aa.num_rows();
00536
00537   #if MTK_DEBUG_LEVEL > 0
00538   std::cout << "Input matrix BEFORE QR factorization:" << std::endl;
00539   std::cout << aa << std::endl;
00540   #endif
00541
00542   #ifdef MTK_PRECISION_DOUBLE
00543   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00544           tau,
00545           work, &lwork, &info);
00546   #else
00547   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00548           tau,
00549           work, &lwork, &info);
00550   #endif
00551
00552   #if MTK_DEBUG_LEVEL > 0
00553   if (info == 0) {
00554     lwork = (int) work[0];
00555   } else {
00556     std::cerr << "Could not get value for lwork on line " << __LINE__ - 5 <<
00557       std::endl;
00558     std::cerr << "Exiting..." << std::endl;
00559   }
00560   #endif
00561
00562   #if MTK_DEBUG_LEVEL>0
00563   std::cout << "lwork = " << std::endl << std::setw(12) << lwork << std::endl
00564     << std::endl;
00565   #endif
00566
```

```
00567   delete [] work;
00568   work = nullptr;
00569
00570   // Once we know lwork, we can actually invoke the factorization:
00571   try {
00572     work = new mtk::Real [lwork];
00573   } catch (std::bad_alloc &memory_allocation_exception) {
00574     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00575       std::endl;
00576     std::cerr << memory_allocation_exception.what() << std::endl;
00577   }
00578   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00579
00580   int ltau = std::min(aaT_num_rows,aaT_num_cols);
00581
00582   try {
00583     tau = new mtk::Real [ltau];
00584   } catch (std::bad_alloc &memory_allocation_exception) {
00585     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00586       std::endl;
00587     std::cerr << memory_allocation_exception.what() << std::endl;
00588   }
00589   memset(tau, mtk::kZero, sizeof(0.0)*ltau);
00590
00591   #ifdef MTK_PRECISION_DOUBLE
00592   dgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00593           tau, work, &lwork, &info);
00594   #else
00595   fgeqrf_(&aaT_num_rows, &aaT_num_cols, aa.data(), &aaT_num_rows,
00596           tau, work, &lwork, &info);
00597   #endif
00598
00599   if (!info) {
00600     #if MTK_DEBUG_LEVEL > 0
00601     std::cout << "QR factorization completed!" << std::endl << std::endl;
00602     #endif
00603   } else {
00604     std::cerr << "Error solving system! info = " << info << std::endl;
00605     std::cerr << "Exiting..." << std::endl;
00606   }
00607
00608   #if MTK_DEBUG_LEVEL > 0
00609   std::cout << "Input matrix AFTER QR factorization:" << std::endl;
00610   std::cout << aa << std::endl;
00611   #endif
00612
00613   // We now generate the real matrix Q with orthonormal columns. This has to
00614   // be done separately since the actual output of dgeqrf_ (AA_) represents
00615   // the orthogonal matrix Q as a product of min(aa_num_rows,aa_num_cols)
00616   // elementary Householder reflectors. Notice that we must re-inquire the new
00617   // value for lwork that is used.
00618
00619   bool padded{false};
00620
00621   bool transpose{false};
00622
00623   mtk::DenseMatrix QQ_(aa.num_cols(),padded,transpose);
00624
00625   #if MTK_DEBUG_LEVEL > 0
00626   std::cout << "Initialized QQ_T: " << std::endl;
00627   std::cout << QQ_ << std::endl;
00628   #endif
00629
00630   // Assemble the QQ_ matrix:
00631   lwork = -1;
00632
00633   delete[] work;
00634   work = nullptr;
00635
00636   try {
00637     work = new mtk::Real[1];
00638   } catch (std::bad_alloc &memory_allocation_exception) {
00639     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00640       std::endl;
00641     std::cerr << memory_allocation_exception.what() <<
00642       std::endl;
00643   }
00644   memset(work, mtk::kZero, sizeof(work[0])*1);
00645
00646   char side_{'L'};
00647   char trans_{'N'};
```

```
00648
00649   int aux = QQ_.num_rows();
00650
00651   #ifdef MTK_PRECISION_DOUBLE
00652   dormqr_(&side_, &trans_,
00653           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00654           QQ_.data(), &aux, work, &lwork, &info);
00655   #else
00656   formqr_(&side_, &trans_,
00657           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00658           QQ_.data(), &aux, work, &lwork, &info);
00659   #endif
00660
00661   #if MTK_DEBUG_LEVEL > 0
00662   if (info == 0) {
00663     lwork = (int) work[0];
00664   } else {
00665     std::cerr << "Could not get lwork on line " << __LINE__ - 5 << std::endl;
00666     std::cerr << "Exiting..." << std::endl;
00667   }
00668   #endif
00669
00670   #if MTK_DEBUG_LEVEL > 0
00671   std::cout << "lwork = " << std::endl << std::setw(12) << lwork <<
00672     std::endl << std::endl;
00673   #endif
00674
00675   delete[] work;
00676   work = nullptr;
00677
00678   try {
00679     work = new mtk::Real[lwork];
00680   } catch (std::bad_alloc &memory_allocation_exception) {
00681     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 <<
00682       std::endl;
00683     std::cerr << memory_allocation_exception.what() << std::endl;
00684   }
00685   memset(work, mtk::kZero, sizeof(work[0])*lwork);
00686
00687   #ifdef MTK_PRECISION_DOUBLE
00688   dormqr_(&side_, &trans_,
00689           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00690           QQ_.data(), &aux, work, &lwork, &info);
00691   #else
00692   formqr_(&side_, &trans_,
00693           &aa_num_cols, &aa_num_cols, &ltau, aa.data(), &aaT_num_rows, tau,
00694           QQ_.data(), &aux, work, &lwork, &info);
00695   #endif
00696
00697   if (!info) {
00698     #if MTK_DEBUG_LEVEL>0
00699     std::cout << "Q matrix successfully assembled!" << std::endl << std::endl;
00700     #endif
00701   } else {
00702     std::cerr << "Something went wrong solving system! info = " << info <<
00703       std::endl;
00704     std::cerr << "Exiting..." << std::endl;
00705   }
00706
00707   delete[] work;
00708   work = nullptr;
00709
00710   delete[] tau;
00711   tau = nullptr;
00712
00713   return QQ_;
00714 }
00715
00716 int mtk::LAPACKAdapter::SolveRectangularDenseSystem(const
      mtk::DenseMatrix &aa,
00717                                                     mtk::Real *ob_,
00718                                                     int ob_ld_) {
00719
00720   // We first invoke the solver to query for the value of lwork. For this,
00721   // we must at least allocate enough space to allow access to WORK(1), or
00722   // work[0]:
00723
00724   // If LWORK = -1, then a workspace query is assumed; the routine only
00725   // calculates the optimal size of the WORK array, returns this value as
00726   // the first entry of the WORK array, and no error message related to
00727   // LWORK is issued by XERBLA.
```

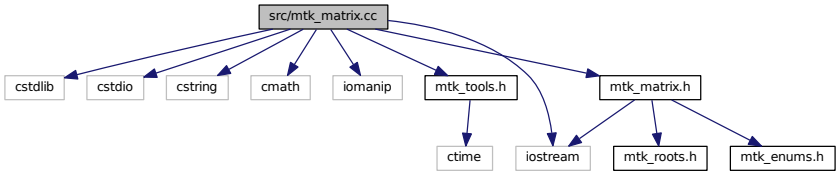
```
00728
00729   mtk::Real *work{}; // Work array.
00730
00731   try {
00732     work = new mtk::Real[1];
00733   } catch (std::bad_alloc &memory_allocation_exception) {
00734     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00735     std::cerr << memory_allocation_exception.what() << std::endl;
00736   }
00737   memset(work, mtk::kZero, sizeof(work[0])*1);
00738
00739   char trans_{'N'};
00740   int nrhs_{1};
00741   int info{0};
00742   int lwork{-1};
00743
00744   int AA_num_rows_  = aa.num_cols();
00745   int AA_num_cols_  = aa.num_rows();
00746   int AA_ld_ = std::max(1,aa.num_cols());
00747
00748   #ifdef MTK_PRECISION_DOUBLE
00749   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00750          ob_, &ob_ld_,
00751          work, &lwork, &info);
00752   #else
00753   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00754          ob_, &ob_ld_,
00755          work, &lwork, &info);
00756   #endif
00757
00758   if (info == 0) {
00759     lwork = (int) work[0];
00760   } else {
00761     std::cerr << "Could not get value for lwork on line " << __LINE__ - 2 <<
00762       std::endl;
00763     std::cerr << "Exiting..." << std::endl;
00764     return info;
00765   }
00766
00767   #if MTK_DEBUG_LEVEL > 0
00768   std::cout << "lwork = " << std::endl << std::setw(12)<< lwork <<
00769     std::endl << std::endl;
00770   #endif
00771
00772   // We then use lwork's new value to create the work array:
00773   delete[] work;
00774   work = nullptr;
00775
00776   try {
00777     work = new mtk::Real[lwork];
00778   } catch (std::bad_alloc &memory_allocation_exception) {
00779     std::cerr << "Memory allocation exception on line " << __LINE__ - 3 << std::endl;
00780     std::cerr << memory_allocation_exception.what() << std::endl;
00781   }
00782   memset(work, 0.0, sizeof(work[0])*lwork);
00783
00784   // We now invoke the solver again:
00785   #ifdef MTK_PRECISION_DOUBLE
00786   dgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00787          ob_, &ob_ld_,
00788          work, &lwork, &info);
00789   #else
00790   sgels_(&trans_, &AA_num_rows_, &AA_num_cols_, &nrhs_, aa.data(), &AA_ld_,
00791          ob_, &ob_ld_,
00792          work, &lwork, &info);
00793   #endif
00794
00795   delete [] work;
00796   work = nullptr;
00797
00798   return info;
00799 }
```

17.47 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:



17.47.1 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.

17.48 mtk_matrix.cc

```
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00018
00019 esanchez at mail dot sdsu dot edu
00020
00021 A copy of the modified files should be reported once modifications are
00022 completed. Documentation related to said modifications should be included.
00023
00024 2. Redistributions of source code must be done through direct
00025 downloads from the project's GitHub page:
00026
00027 http://www.csrc.sdsu.edu/mtk
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00056 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00057 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00058 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00059 */
00060
00061 #include <cstdlib>
00062 #include <cstdio>
00063 #include <cstring>
00064 #include <cmath>
00065
00066 #include <iomanip>
00067 #include <iostream>
00068
00069 #include "mtk_tools.h"
00070 #include "mtk_matrix.h"
00071
00072 mtk::Matrix::Matrix():
00073   storage_(mtk::DENSE),
00074   ordering_(mtk::ROW_MAJOR),
00075   num_rows_(),
00076   num_cols_(),
00077   num_values_(),
00078   ld_(),
00079   num_zero_(),
00080   num_non_zero_(),
00081   num_null_(),
00082   num_non_null_(),
00083   kl_(),
00084   ku_(),
00085   bandwidth_(),
00086   abs_density_(),
00087   rel_density_(),
00088   abs_sparsity_(),
00089   rel_sparsity_() {}
00090
00091 mtk::Matrix::Matrix(const Matrix &in):
00092   storage_(in.storage_),
00093   ordering_(in.ordering_),
00094   num_rows_(in.num_rows_),
00095   num_cols_(in.num_cols_),
00096   num_values_(in.num_values_),
00097   ld_(in.ld_),
00098   num_zero_(in.num_zero_),
00099   num_non_zero_(in.num_non_zero_),
00100   num_null_(in.num_null_),
00101   num_non_null_(in.num_non_null_),
00102   kl_(in.kl_),
00103   ku_(in.ku_),
00104   bandwidth_(in.bandwidth_),
00105   abs_density_(in.abs_density_),
00106   rel_density_(in.rel_density_),
00107   abs_sparsity_(in.abs_sparsity_),
00108   rel_sparsity_(in.rel_sparsity_) {}
00109
00110 mtk::Matrix::~Matrix() {}
00111
00112 mtk::MatrixStorage mtk::Matrix::storage() const {
00113
00114   return storage_;
00115 }
00116
00117 mtk::MatrixOrdering mtk::Matrix::ordering() const {
00118
```

```
00119   return ordering_;
00120 }
00121
00122 int mtk::Matrix::num_rows() const {
00123
00124   return num_rows_;
00125 }
00126
00127 int mtk::Matrix::num_cols() const {
00128
00129   return num_cols_;
00130 }
00131
00132 int mtk::Matrix::num_values() const {
00133
00134   return num_values_;
00135 }
00136
00137 int mtk::Matrix::ld() const {
00138
00139   return ld_;
00140 }
00141
00142 int mtk::Matrix::num_zero() const {
00143
00144   return num_zero_;
00145 }
00146
00147 int mtk::Matrix::num_non_zero() const {
00148
00149   return num_non_zero_;
00150 }
00151
00152 int mtk::Matrix::num_null() const {
00153
00154   return num_null_;
00155 }
00156
00157 int mtk::Matrix::num_non_null() const {
00158
00159   return num_non_null_;
00160 }
00161
00162 int mtk::Matrix::kl() const {
00163
00164   return kl_;
00165 }
00166
00167 int mtk::Matrix::ku() const {
00168
00169   return ku_;
00170 }
00171
00172 int mtk::Matrix::bandwidth() const {
00173
00174   return bandwidth_;
00175 }
00176
00177 mtk::Real mtk::Matrix::rel_density() const {
00178
00179   return rel_density_;
00180 }
00181
00182 mtk::Real mtk::Matrix::abs_sparsity() const {
00183
00184   return abs_sparsity_;
00185 }
00186
00187 mtk::Real mtk::Matrix::rel_sparsity() const {
00188
00189   return rel_sparsity_;
00190 }
00191
00192 void mtk::Matrix::set_storage(const mtk::MatrixStorage &ss) {
00193
00194   #if MTK_DEBUG_LEVEL > 0
00195   mtk::Tools::Prevent(!(ss == mtk::DENSE ||
00196                         ss == mtk::BANDED ||
00197                         ss == mtk::CRS),
00198                       __FILE__, __LINE__, __func__);
00199   #endif
```

```
00200
00201   storage_ = ss;
00202 }
00203
00204 void mtk::Matrix::set_ordering(const
      mtk::MatrixOrdering &oo) {
00205
00206   #if MTK_DEBUG_LEVEL > 0
00207   mtk::Tools::Prevent(!(oo == mtk::ROW_MAJOR || oo ==
      mtk::COL_MAJOR),
00208                       __FILE__, __LINE__, __func__);
00209   #endif
00210
00211   ordering_ = oo;
00212
00213   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00214     std::max(1,num_cols_): std::max(1,num_rows_);
00215 }
00216
00217 void mtk::Matrix::set_num_rows(int in) {
00218
00219   #if MTK_DEBUG_LEVEL > 0
00220   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00221   #endif
00222
00223   num_rows_ = in;
00224   num_values_ = num_rows_*num_cols_;
00225   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00226     std::max(1,num_cols_): std::max(1,num_rows_);
00227 }
00228
00229 void mtk::Matrix::set_num_cols(int in) {
00230
00231   #if MTK_DEBUG_LEVEL > 0
00232   mtk::Tools::Prevent(in < 1, __FILE__, __LINE__, __func__);
00233   #endif
00234
00235   num_cols_ = in;
00236   num_values_ = num_rows_*num_cols_;
00237   ld_ = (ordering_ == mtk::ROW_MAJOR)?
00238     std::max(1,num_cols_): std::max(1,num_rows_);
00239 }
00240
00241 void mtk::Matrix::set_num_zero(int in) {
00242
00243   #if MTK_DEBUG_LEVEL > 0
00244   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00245   #endif
00246
00247   num_zero_ = in;
00248   num_non_zero_ = num_values_ - num_zero_;
00249
00251   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00252   rel_sparsity_ = 1.0 - rel_density_;
00253 }
00254
00255 void mtk::Matrix::set_num_null(int in) {
00256
00257   #if MTK_DEBUG_LEVEL > 0
00258   mtk::Tools::Prevent(in < 0, __FILE__, __LINE__, __func__);
00259   #endif
00260
00261   num_null_ = in;
00262   num_non_null_ = num_values_ - num_null_;
00263
00265   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00266   abs_sparsity_ = 1.0 - abs_density_;
00267 }
00268
00269 void mtk::Matrix::IncreaseNumZero() {
00270
00272
00273   num_zero_++;
00274   num_non_zero_ = num_values_ - num_zero_;
00275   rel_density_ = (mtk::Real) num_non_zero_/num_values_;
00276   rel_sparsity_ = 1.0 - rel_density_;
00277 }
00278
00279 void mtk::Matrix::IncreaseNumNull() {
00280
00282
```

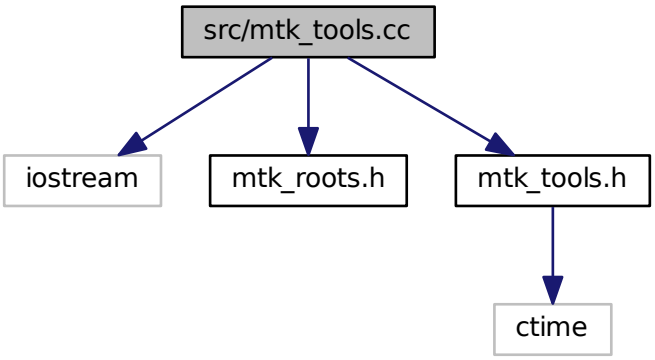
```
00283   num_null_++;
00284   num_non_null_ = num_values_ - num_null_;
00285   abs_density_ = (mtk::Real) num_non_null_/num_values_;
00286   abs_sparsity_ = 1.0 - abs_density_;
00287 }
```

17.49 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:



17.49.1 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.

17.50 mtk_tools.cc

```
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00018 and a copy of the modified files should be reported once modifications are
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00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #include <iostream>
00057
00058 #include "mtk_roots.h"
00059 #include "mtk_tools.h"
00060
00061 void mtk::Tools::Prevent(const bool condition,
00062                          const char *fname,
00063                          int lineno,
00064                          const char *fxname) {
00065
00067
00068   #if MTK_DEBUG_LEVEL > 0
00069   if (lineno < 1) {
00070     std::cerr << __FILE__ << ": " << "Incorrect parameter at line " <<
00071     __LINE__ - 2 << " (" << __func__ << ")" << std::endl;
00072     exit(EXIT_FAILURE);
00073   }
00074   #endif
00075
00076   if (condition) {
00077     std::cerr << fname << ": " << "Incorrect parameter at line " <<
00078     lineno << " (" << fxname << ")" << std::endl;
00079     exit(EXIT_FAILURE);
00080   }
00081 }
00082
00084
00085 int mtk::Tools::test_number_; // Used to control the correctness of the test.
00086
00087 clock_t mtk::Tools::begin_time_;  // Used to time tests.
00088
00089 void mtk::Tools::BeginTestNo(const int &nn) {
00090
00091   #if MTK_DEBUG_LEVEL > 0
00092   mtk::Tools::Prevent(nn <= 0, __FILE__, __LINE__, __func__);
00093   #endif
00094
00095   test_number_ = nn;
00096
00097   std::cout << "Test " << nn << "..." << std::endl << std::endl;
00098   begin_time_ = clock();
00099 }
```

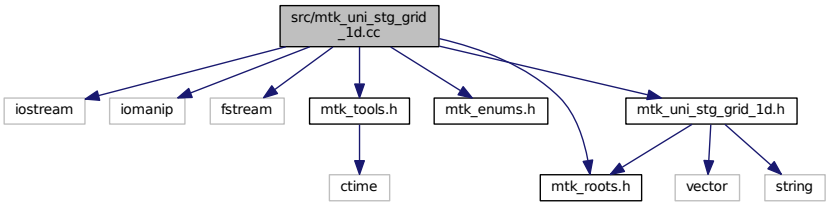
```
00100
00101 void mtk::Tools::EndTestNo(const int &nn) {
00102
00103   #if MTK_DEBUG_LEVEL > 0
00104   mtk::Tools::Prevent(test_number_ != nn, __FILE__, __LINE__, __func__);
00105   #endif
00106
00107   auto duration = mtk::Real(clock() - begin_time_)/CLOCKS_PER_SEC;
00108   std::cout << "Test " << test_number_ << " complete! ";
00109   std::cout << "Elapsed: " << duration << " seconds." << std::endl;
00110 }
```

17.51 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)

17.51.1 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.

17.52 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. Documentation related to said modifications should be included.
00020
00021 2. Redistributions of source code must be done through direct
00022 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
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00054 */
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <fstream>
00059
00060 #include "mtk_roots.h"
00061 #include "mtk_enums.h"
00062 #include "mtk_tools.h"
00063
00064 #include "mtk_uni_stg_grid_1d.h"
00065
00066 namespace mtk {
00067
00068 std::ostream& operator <<(std::ostream &stream, mtk::UniStgGrid1D &in) {
00069
00070   stream << '[' << in.west_bndy_x_ << ':' << in.num_cells_x_ << ':' <<
00071   in.east_bndy_x_ << "] = " << std::endl << std::endl;
00072
00074
00075   stream << "x:";
00076   for (unsigned int ii = 0; ii < in.discrete_domain_x_.size(); ++ii) {
00077     stream << std::setw(10) << in.discrete_domain_x_[ii];
00078   }
00079   stream << std::endl;
00080
00081   if (in.nature_ == mtk::SCALAR) {
00082     stream << "u:";
00083   }
00084   else {
00085     stream << "v:";
00086   }
00087   for (unsigned int ii = 0; ii < in.discrete_field_u_.size(); ++ii) {
```

```
00088     stream << std::setw(10) << in.discrete_field_u_[ii];
00089   }
00090
00091   stream << std::endl;
00092
00093   return stream;
00094 }
00095 }
00096
00097 mtk::UniStgGrid1D::UniStgGrid1D():
00098     nature_(),
00099     discrete_domain_x_(),
00100     discrete_field_u_(),
00101     west_bndy_x_(),
00102     east_bndy_x_(),
00103     num_cells_x_(),
00104     delta_x_() {}
00105
00106 mtk::UniStgGrid1D::UniStgGrid1D(const
      UniStgGrid1D &grid):
00107     nature_(grid.nature_),
00108     west_bndy_x_(grid.west_bndy_x_),
00109     east_bndy_x_(grid.east_bndy_x_),
00110     num_cells_x_(grid.num_cells_x_),
00111     delta_x_(grid.delta_x_) {
00112
00113     std::copy(grid.discrete_domain_x_.begin(),
00114               grid.discrete_domain_x_.begin() + grid.
      discrete_domain_x_.size(),
00115               discrete_domain_x_.begin());
00116
00117     std::copy(grid.discrete_field_u_.begin(),
00118               grid.discrete_field_u_.begin() + grid.
      discrete_field_u_.size(),
00119               discrete_field_u_.begin());
00120 }
00121
00122 mtk::UniStgGrid1D::UniStgGrid1D(const Real &west_bndy_x,
00123                                 const Real &east_bndy_x,
00124                                 const int &num_cells_x,
00125                                 const mtk::FieldNature &nature) {
00126
00127   #if MTK_DEBUG_LEVEL > 0
00128   mtk::Tools::Prevent(west_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00129   mtk::Tools::Prevent(east_bndy_x < mtk::kZero, __FILE__, __LINE__, __func__);
00130   mtk::Tools::Prevent(east_bndy_x <= west_bndy_x, __FILE__, __LINE__, __func__);
00131   mtk::Tools::Prevent(num_cells_x < 0, __FILE__, __LINE__, __func__);
00132   #endif
00133
00134   nature_ = nature;
00135   west_bndy_x_ = west_bndy_x;
00136   east_bndy_x_ = east_bndy_x;
00137   num_cells_x_ = num_cells_x;
00138
00139   delta_x_ = (east_bndy_x - west_bndy_x)/((mtk::Real) num_cells_x);
00140 }
00141
00142 mtk::UniStgGrid1D::~UniStgGrid1D() {}
00143
00144 mtk::Real mtk::UniStgGrid1D::delta_x() const {
00145
00146   return delta_x_;
00147 }
00148
00149 mtk::Real *mtk::UniStgGrid1D::discrete_domain_x() {
00150
00151   return discrete_domain_x_.data();
00152 }
00153
00154 mtk::Real *mtk::UniStgGrid1D::discrete_field_u() {
00155
00156   return discrete_field_u_.data();
00157 }
00158
00159 int mtk::UniStgGrid1D::num_cells_x() const {
00160
00161   return num_cells_x_;
00162 }
00163
00164 void mtk::UniStgGrid1D::BindScalarField(
00165     mtk::Real (*ScalarField)(mtk::Real xx)) {
```

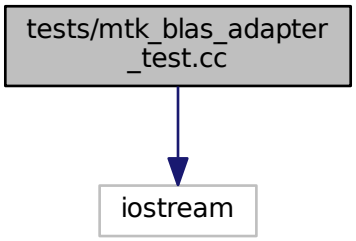
```
00166
00167   #if MTK_DEBUG_LEVEL > 0
00168   mtk::Tools::Prevent(nature_ == mtk::VECTOR, __FILE__, __LINE__, __func__);
00169   #endif
00170
00172
00173   discrete_domain_x_.reserve(num_cells_x_ + 2);
00174
00175   discrete_domain_x_.push_back(west_bndy_x_);
00176   #ifdef MTK_PRECISION_DOUBLE
00177   auto first_center = west_bndy_x_ + delta_x_/2.0;
00178   #else
00179   auto first_center = west_bndy_x_ + delta_x_/2.0f;
00180   #endif
00181   discrete_domain_x_.push_back(first_center);
00182   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00183     discrete_domain_x_.push_back(first_center + ii*delta_x_);
00184   }
00185   discrete_domain_x_.push_back(east_bndy_x_);
00186
00188
00189   discrete_field_u_.reserve(num_cells_x_ + 2);
00190
00191   discrete_field_u_.push_back(ScalarField(west_bndy_x_));
00192
00193   discrete_field_u_.push_back(ScalarField(first_center));
00194   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00195     discrete_field_u_.push_back(ScalarField(first_center + ii*delta_x_));
00196   }
00197   discrete_field_u_.push_back(ScalarField(east_bndy_x_));
00198 }
00199
00200 void mtk::UniStgGrid1D::BindVectorField(
00201     mtk::Real (*VectorField)(mtk::Real xx)) {
00202
00203   #if MTK_DEBUG_LEVEL > 0
00204   mtk::Tools::Prevent(nature_ == mtk::SCALAR, __FILE__, __LINE__, __func__);
00205   #endif
00206
00208
00209   discrete_domain_x_.reserve(num_cells_x_ + 1);
00210
00211   discrete_domain_x_.push_back(west_bndy_x_);
00212   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00213     discrete_domain_x_.push_back(west_bndy_x_ + ii*delta_x_);
00214   }
00215   discrete_domain_x_.push_back(east_bndy_x_);
00216
00218
00219   discrete_field_u_.reserve(num_cells_x_ + 1);
00220
00221   discrete_field_u_.push_back(VectorField(west_bndy_x_));
00222   for (auto ii = 1; ii < num_cells_x_; ++ii) {
00223     discrete_field_u_.push_back(VectorField(west_bndy_x_ + ii*delta_x_));
00224   }
00225   discrete_field_u_.push_back(VectorField(east_bndy_x_));
00226 }
00227
00228 bool mtk::UniStgGrid1D::WriteToFile(std::string filename,
00229                                     std::string space_name,
00230                                     std::string field_name) {
00231
00232   std::ofstream output_dat_file;  // Output file.
00233
00234   output_dat_file.open(filename);
00235
00236   if (!output_dat_file.is_open()) {
00237     return false;
00238   }
00239
00240   output_dat_file << "# " << space_name <<  ' ' << field_name << std::endl;
00241   for (unsigned int ii = 0; ii < discrete_domain_x_.size(); ++ii) {
00242     output_dat_file << discrete_domain_x_[ii] << ' ' << discrete_field_u_[ii] <<
00243       std::endl;
00244   }
00245
00246   output_dat_file.close();
00247
00248   return true;
00249 }
```

17.53 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 ()

17.53.1 Detailed Description

Author

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

Definition in file mtk_blas_adapter_test.cc.

17.53.2 Function Documentation

17.53.2.1 int main ( )

Definition at line 107 of file mtk_blas_adapter_test.cc.

17.54 mtk_blas_adapter_test.cc

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

```
00018
00019 2. Redistributions of source code must be done through direct
00020 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00021
00022 3. Redistributions of source code must retain the above copyright notice, this
00023 list of conditions and the following disclaimer.
00024
00025 4. Redistributions in binary form must reproduce the above copyright notice,
00026 this list of conditions and the following disclaimer in the documentation and/or
00027 other materials provided with the distribution.
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00029 5. Usage of the binary form on proprietary applications shall require explicit
00030 prior written permission from the the copyright holders.
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00041
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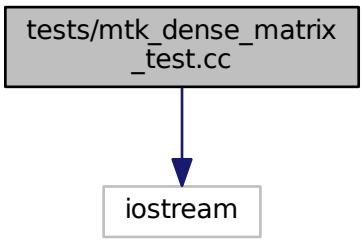
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void Test1() {
00061
00062   mtk::Tools::BeginTestNo(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   std::cout << aa << std::endl;
00077
00078   mtk::DenseMatrix bb(cc,rr);
00079
00080   bb.SetValue(0,0,7.0);
00081   bb.SetValue(0,1,8.0);
00082   bb.SetValue(1,0,9.0);
00083   bb.SetValue(1,1,10.0);
00084   bb.SetValue(2,0,11.0);
00085   bb.SetValue(2,1,12.0);
00086
00087   std::cout << bb << std::endl;
00088
00089   mtk::DenseMatrix pp = mtk::BLASAdapter::RealDenseMM(aa,bb);
00090
00091   std::cout << pp << std::endl;
00092
00093   mtk::Tools::EndTestNo(1);
00094 }
00095
00096 int main () {
00097
00098   std::cout << "Testing mtk::BLASAdapter class." << std::endl;
```

```
00099
00100   Test1();
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
```

17.55 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 ()

17.55.1 Detailed Description

Author

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

Definition in file mtk_dense_matrix_test.cc.

17.55.2 Function Documentation

17.55.2.1 int main ( )

Definition at line 285 of file mtk_dense_matrix_test.cc.

17.56 mtk_dense_matrix_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed. Documentation related to said modifications should be included.
00018
00019 2. Redistributions of source code must be done through direct
00020 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00021
00022 3. Redistributions of source code must retain the above copyright notice, this
00023 list of conditions and the following disclaimer.
00024
00025 4. Redistributions in binary form must reproduce the above copyright notice,
00026 this list of conditions and the following disclaimer in the documentation and/or
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00028
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void Test1() {
00062
00063   mtk::Tools::BeginTestNo(1);
00064
00065   mtk::DenseMatrix m1;
00066
00067   std::cout << m1 << std::endl;
00068
00069   mtk::Tools::EndTestNo(1);
00070 }
00071
00072 void Test2() {
00073
00074   mtk::Tools::BeginTestNo(2);
00075
00076   int rr = 4;
00077   int cc = 7;
00078
00079   mtk::DenseMatrix m2(rr,cc);
00080
00081   std::cout << m2 << std::endl;
00082
00083   mtk::Tools::EndTestNo(2);
00084 }
```

```
00085
00086 void Test3() {
00087
00088   mtk::Tools::BeginTestNo(3);
00089
00090   int rank = 5;
00091   bool padded = true;
00092   bool transpose = false;
00093
00094   mtk::DenseMatrix m3(rank,padded,transpose);
00095
00096   std::cout << m3 << std::endl;
00097
00098   mtk::Tools::EndTestNo(3);
00099 }
00100
00101 void Test4() {
00102
00103   mtk::Tools::BeginTestNo(4);
00104
00105   int rank = 5;
00106   bool padded = false;
00107   bool transpose = false;
00108
00109   mtk::DenseMatrix m4(rank,padded,transpose);
00110
00111   std::cout << m4 << std::endl;
00112
00113   mtk::Tools::EndTestNo(4);
00114 }
00115
00116 void Test5() {
00117
00118   mtk::Tools::BeginTestNo(5);
00119
00120   int rr = 4;
00121   int cc = 7;
00122
00123   mtk::DenseMatrix m5(rr,cc);
00124
00125   for (auto ii = 0; ii < rr; ++ii) {
00126     for (auto jj = 0; jj < cc; ++jj) {
00127       m5.SetValue(ii,jj,(mtk::Real) ii + jj);
00128     }
00129   }
00130
00131   std::cout << m5 << std::endl;
00132
00133   mtk::Real *vals = m5.data();
00134
00135   for (auto ii = 0; ii < rr; ++ii) {
00136     for (auto jj = 0; jj < cc; ++jj) {
00137       std::cout << " " << vals[ii*cc + jj];
00138     }
00139     std::cout << std::endl;
00140   }
00141   std::cout << std::endl;
00142
00143   for (auto ii = 0; ii < rr; ++ii) {
00144     for (auto jj = 0; jj < cc; ++jj) {
00145       std::cout << " " << m5.GetValue(ii,jj);
00146     }
00147     std::cout << std::endl;
00148   }
00149   std::cout << std::endl;
00150
00151   mtk::Tools::EndTestNo(5);
00152 }
00153
00154 void Test6() {
00155
00156   mtk::Tools::BeginTestNo(6);
00157
00158   bool transpose = false;
00159   int generator_length = 3;
00160   int progression_length = 4;
00161
00162   mtk::Real generator[] = {-0.5, 0.5, 1.5};
00163
00164   mtk::DenseMatrix m6(generator,generator_length,progression_length,transpose);
00165
```

```
00166   std::cout << m6 << std::endl;
00167
00168   transpose = true;
00169
00170   mtk::DenseMatrix m7(generator,generator_length,progression_length,transpose);
00171
00172   std::cout << m7 << std::endl;
00173
00174
00175   mtk::Tools::EndTestNo(6);
00176 }
00177
00178 void Test7() {
00179
00180   mtk::Tools::BeginTestNo(7);
00181
00182   bool padded = false;
00183   bool transpose = false;
00184   int lots_of_rows = 2;
00185   int lots_of_cols = 5;
00186   mtk::DenseMatrix m8(lots_of_rows,padded,transpose);
00187
00188   std::cout << m8 << std::endl;
00189
00190   mtk::DenseMatrix m9(lots_of_rows,lots_of_cols);
00191
00192   for (auto ii = 0; ii < lots_of_rows; ++ii) {
00193     for (auto jj = 0; jj < lots_of_cols; ++jj) {
00194       m9.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00195     }
00196   }
00197
00198   std::cout << m9 << std::endl;
00199
00200   mtk::DenseMatrix m10 = mtk::DenseMatrix::Kron(m8,m9);
00201
00202   std::cout << m10 << std::endl;
00203
00204   mtk::Tools::EndTestNo(7);
00205 }
00206
00207 void Test8() {
00208
00209   mtk::Tools::BeginTestNo(8);
00210
00211   int lots_of_rows = 4;
00212   int lots_of_cols = 3;
00213   mtk::DenseMatrix m11(lots_of_rows,lots_of_cols);
00214
00215   for (auto ii = 0; ii < lots_of_rows; ++ii) {
00216     for (auto jj = 0; jj < lots_of_cols; ++jj) {
00217       m11.SetValue(ii,jj,(mtk::Real) ii*lots_of_cols + jj + 1);
00218     }
00219   }
00220
00221   std::cout << m11 << std::endl;
00222
00223   m11.Transpose();
00224
00225   std::cout << m11 << std::endl;
00226
00227   mtk::DenseMatrix m12;
00228
00229   m12 = m11;
00230
00231   std::cout << m12 << std::endl;
00232
00233   mtk::Tools::EndTestNo(8);
00234 }
00235
00236 void Test9() {
00237
00238   mtk::Tools::BeginTestNo(9);
00239
00240   bool transpose = false;
00241   int gg_l = 3;
00242   int progression_length = 4;
00243   mtk::Real gg[] = {-0.5, 0.5, 1.5};
00244
00245   mtk::DenseMatrix m13(gg, gg_l ,progression_length, transpose);
00246
```

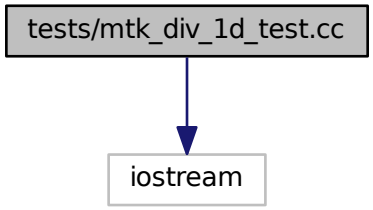
```
00247   std::cout << m13 << std::endl;
00248
00249   mtk::DenseMatrix m14;
00250
00251   m14 = m13;
00252
00253   std::cout << m14 << std::endl;
00254
00255   m13.Transpose();
00256
00257   std::cout << m13 << std::endl;
00258
00259   m14 = m13;
00260
00261   std::cout << m14 << std::endl;
00262
00263   mtk::Tools::EndTestNo(9);
00264 }
00265
00266 int main () {
00267
00268   std::cout << "Testing mtk::DenseMatrix class." << std::endl;
00269
00270   Test1();
00271   Test2();
00272   Test3();
00273   Test4();
00274   Test5();
00275   Test6();
00276   Test7();
00277   Test8();
00278   Test9();
00279 }
00280
00281 #else
00282 #include <iostream>
00283 using std::cout;
00284 using std::endl;
00285 int main () {
00286   cout << "This code HAS to be compiled with support for C++11." << endl;
00287   cout << "Exiting..." << endl;
00288 }
00289 #endif
```

17.57 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 ()

17.57.1 Detailed Description

Author

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

Definition in file mtk_div_1d_test.cc.

17.57.2 Function Documentation

17.57.2.1 int main ( )

Definition at line 248 of file mtk_div_1d_test.cc.

17.58 mtk_div_1d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed. Documentation related to said modifications should be included.
00018
00019 2. Redistributions of source code must be done through direct
00020 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00021
00022 3. Redistributions of source code must retain the above copyright notice, this
00023 list of conditions and the following disclaimer.
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00025 4. Redistributions in binary form must reproduce the above copyright notice,
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00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
```

```
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void Test1() {
00061
00062   mtk::Tools::BeginTestNo(1);
00063
00064   mtk::Div1D div2;
00065
00066   bool info = div2.ConstructDiv1D();
00067
00068   if (!info) {
00069     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00070   }
00071
00072   std::cout << div2 << std::endl;
00073
00074   mtk::Tools::EndTestNo(1);
00075 }
00076
00077 void Test2() {
00078
00079   mtk::Tools::BeginTestNo(2);
00080
00081   mtk::Div1D div4;
00082
00083   bool info = div4.ConstructDiv1D(4);
00084
00085   if (!info) {
00086     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00087   }
00088
00089   std::cout << div4 << std::endl;
00090
00091   mtk::Tools::EndTestNo(2);
00092 }
00093
00094 void Test3() {
00095
00096   mtk::Tools::BeginTestNo(3);
00097
00098   mtk::Div1D div6;
00099
00100   bool info = div6.ConstructDiv1D(6);
00101
00102   if (!info) {
00103     std::cerr << "Mimetic div (6th order) could not be built." << std::endl;
00104   }
00105
00106   std::cout << div6 << std::endl;
00107
00108   mtk::Tools::EndTestNo(3);
00109 }
00110
00111 void Test4() {
00112
00113   mtk::Tools::BeginTestNo(4);
00114
00115   mtk::Div1D div8;
00116
00117   bool info = div8.ConstructDiv1D(8);
00118
00119   if (!info) {
00120     std::cerr << "Mimetic div (8th order) could not be built." << std::endl;
00121   }
00122
00123   std::cout << div8 << std::endl;
00124
00125   mtk::Tools::EndTestNo(4);
00126 }
00127
00128 void Test5() {
00129
00130   mtk::Tools::BeginTestNo(5);
00131
00132   mtk::Div1D div10;
00133
00134   bool info = div10.ConstructDiv1D(10);
```

```
00135
00136   if (!info) {
00137     std::cerr << "Mimetic div (10th order) could not be built." << std::endl;
00138   }
00139
00140   std::cout << div10 << std::endl;
00141
00142   mtk::Tools::EndTestNo(5);
00143 }
00144
00145 void Test6() {
00146
00147   mtk::Tools::BeginTestNo(6);
00148
00149   mtk::Div1D div12;
00150
00151   bool info = div12.ConstructDiv1D(12);
00152
00153   if (!info) {
00154     std::cerr << "Mimetic div (12th order) could not be built." << std::endl;
00155   }
00156
00157   std::cout << div12 << std::endl;
00158
00159   mtk::Tools::EndTestNo(6);
00160 }
00161
00162 void Test7() {
00163
00164   mtk::Tools::BeginTestNo(7);
00165
00166   mtk::Div1D div14;
00167
00168   bool info = div14.ConstructDiv1D(14);
00169
00170   if (!info) {
00171     std::cerr << "Mimetic div (14th order) could not be built." << std::endl;
00172   }
00173
00174   std::cout << div14 << std::endl;
00175
00176   mtk::Tools::EndTestNo(7);
00177 }
00178
00179 void Test8() {
00180
00181   mtk::Tools::BeginTestNo(8);
00182
00183   mtk::Div1D div2;
00184
00185   bool info = div2.ConstructDiv1D();
00186
00187   if (!info) {
00188     std::cerr << "Mimetic div (2nd order) could not be built." << std::endl;
00189   }
00190
00191   std::cout << div2 << std::endl;
00192
00193   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00194
00195   std::cout << grid << std::endl;
00196
00197   mtk::DenseMatrix div2m(div2.ReturnAsDenseMatrix(grid));
00198
00199   std::cout << div2m << std::endl;
00200
00201   mtk::Tools::EndTestNo(8);
00202 }
00203
00204 void Test9() {
00205
00206   mtk::Tools::BeginTestNo(9);
00207
00208   mtk::Div1D div4;
00209
00210   bool info = div4.ConstructDiv1D(4);
00211
00212   if (!info) {
00213     std::cerr << "Mimetic div (4th order) could not be built." << std::endl;
00214   }
00215
```

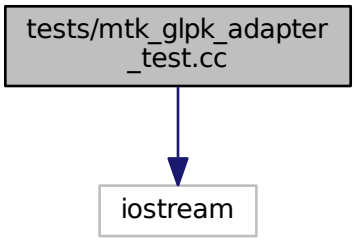
```
00216   std::cout << div4 << std::endl;
00217
00218   mtk::UniStgGrid1D grid(0.0, 1.0, 11);
00219
00220   std::cout << grid << std::endl;
00221
00222   mtk::DenseMatrix div4m(div4.ReturnAsDenseMatrix(grid));
00223
00224   std::cout << div4m << std::endl;
00225
00226   mtk::Tools::EndTestNo(9);
00227 }
00228
00229 int main () {
00230
00231   std::cout << "Testing mtk::Div1D class." << std::endl;
00232
00233   Test1();
00234   Test2();
00235   Test3();
00236   Test4();
00237   Test5();
00238   Test6();
00239   Test7();
00240   Test8();
00241   Test9();
00242 }
00243
00244 #else
00245 #include <iostream>
00246 using std::cout;
00247 using std::endl;
00248 int main () {
00249   cout << "This code HAS to be compiled with support for C++11." << endl;
00250   cout << "Exiting..." << endl;
00251 }
00252 #endif
```

17.59 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 ()

17.59.1 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.

17.59.2 Function Documentation

17.59.2.1 int main ( )

Definition at line 81 of file mtk_glpk_adapter_test.cc.

17.60 mtk_glpk_adapter_test.cc

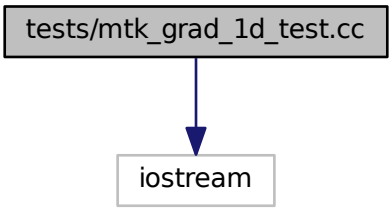
```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed. Documentation related to said modifications should be included.
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 of source code must retain the above copyright notice, this
00025 list of conditions and the following disclaimer.
00026
00027 4. 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 5. Usage of the binary form on proprietary applications shall require explicit
00032 prior written permission from the the copyright holders.
00033
00034 6. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
00037
00038 The copyright holders provide no reassurances that the source code provided does
00039 not infringe any patent, copyright, or any other intellectual property rights of
00040 third parties. The copyright holders disclaim any liability to any recipient for
00041 claims brought against recipient by any third party for infringement of that
00042 parties intellectual property rights.
00043
00044 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
```

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

17.61 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 ()

17.61.1 Detailed Description

Author

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

Definition in file mtk_grad_1d_test.cc.

17.61.2 Function Documentation

17.61.2.1 int main ( )

Definition at line 186 of file mtk_grad_1d_test.cc.

17.62 mtk_grad_1d_test.cc

```
00001
00008 /*
00009 Copyright (C) 2015, Computational Science Research Center, San Diego State
00010 University. All rights reserved.
00011
00012 Redistribution and use in source and binary forms, with or without modification,
00013 are permitted provided that the following conditions are met:
00014
00015 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00016 and a copy of the modified files should be reported once modifications are
00017 completed. Documentation related to said modifications should be included.
00018
00019 2. Redistributions of source code must be done through direct
00020 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00021
00022 3. Redistributions of source code must retain the above copyright notice, this
00023 list of conditions and the following disclaimer.
00024
00025 4. Redistributions in binary form must reproduce the above copyright notice,
00026 this list of conditions and the following disclaimer in the documentation and/or
00027 other materials provided with the distribution.
00028
00029 5. Usage of the binary form on proprietary applications shall require explicit
00030 prior written permission from the the copyright holders.
00031
00032 6. Neither the name of the copyright holder nor the names of its contributors
00033 may be used to endorse or promote products derived from this software without
00034 specific prior written permission.
00035
00036 The copyright holders provide no reassurances that the source code provided does
00037 not infringe any patent, copyright, or any other intellectual property rights of
00038 third parties. The copyright holders disclaim any liability to any recipient for
00039 claims brought against recipient by any third party for infringement of that
00040 parties intellectual property rights.
00041
00042 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00043 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00044 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00045 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00046 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00047 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00048 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057
00058 #include "mtk.h"
00059
00060 void Test1() {
00061
00062   mtk::Tools::BeginTestNo(1);
00063
00064   mtk::Grad1D grad2;
00065
00066   bool info = grad2.ConstructGrad1D();
00067
00068   if (!info) {
00069     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
00070   }
00071
00072   std::cout << grad2 << std::endl;
00073
```

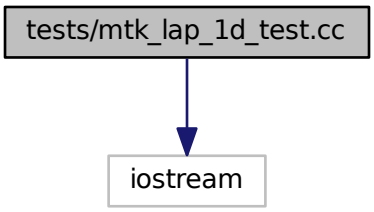
```
00074   mtk::Tools::EndTestNo(1);
00075 }
00076
00077 void Test2() {
00078
00079   mtk::Tools::BeginTestNo(2);
00080
00081   mtk::Grad1D grad4;
00082
00083   bool info = grad4.ConstructGrad1D(4);
00084
00085   if (!info) {
00086     std::cerr << "Mimetic grad (4th order) could not be built." << std::endl;
00087   }
00088
00089   std::cout << grad4 << std::endl;
00090
00091   mtk::Tools::EndTestNo(2);
00092 }
00093
00094 void Test3() {
00095
00096   mtk::Tools::BeginTestNo(3);
00097
00098   mtk::Grad1D grad6;
00099
00100   bool info = grad6.ConstructGrad1D(6);
00101
00102   if (!info) {
00103     std::cerr << "Mimetic grad (6th order) could not be built." << std::endl;
00104   }
00105
00106   std::cout << grad6 << std::endl;
00107
00108   mtk::Tools::EndTestNo(3);
00109 }
00110
00111 void Test4() {
00112
00113   mtk::Tools::BeginTestNo(4);
00114
00115   mtk::Grad1D grad8;
00116
00117   bool info = grad8.ConstructGrad1D(8);
00118
00119   if (!info) {
00120     std::cerr << "Mimetic grad (8th order) could not be built." << std::endl;
00121   }
00122
00123   std::cout << grad8 << std::endl;
00124
00125   mtk::Tools::EndTestNo(4);
00126 }
00127
00128 void Test5() {
00129
00130   mtk::Tools::BeginTestNo(5);
00131
00132   mtk::Grad1D grad10;
00133
00134   bool info = grad10.ConstructGrad1D(10);
00135
00136   if (!info) {
00137     std::cerr << "Mimetic grad (10th order) could not be built." << std::endl;
00138   }
00139
00140   std::cout << grad10 << std::endl;
00141
00142   mtk::Tools::EndTestNo(5);
00143 }
00144
00145 void Test6() {
00146
00147   mtk::Tools::BeginTestNo(6);
00148
00149   mtk::Grad1D grad2;
00150
00151   bool info = grad2.ConstructGrad1D();
00152
00153   if (!info) {
00154     std::cerr << "Mimetic grad (2nd order) could not be built." << std::endl;
```

```
00155   }
00156
00157   std::cout << grad2 << std::endl;
00158
00159   mtk::UniStgGrid1D grid(0.0, 1.0, 5);
00160
00161   std::cout << grid << std::endl;
00162
00163   mtk::DenseMatrix grad2m(grad2.ReturnAsDenseMatrix(grid));
00164
00165   std::cout << grad2m << std::endl;
00166
00167   mtk::Tools::EndTestNo(6);
00168 }
00169
00170 int main () {
00171
00172   std::cout << "Testing mtk::Grad1D class." << std::endl;
00173
00174   Test1();
00175   Test2();
00176   Test3();
00177   Test4();
00178   Test5();
00179   Test6();
00180 }
00181
00182 #else
00183 #include <iostream>
00184 using std::cout;
00185 using std::endl;
00186 int main () {
00187   cout << "This code HAS to be compiled with support for C++11." << endl;
00188   cout << "Exiting..." << endl;
00189 }
00190 #endif
```

17.63 tests/mtk_lap_1d_test.cc File Reference

`#include <iostream>`

Include dependency graph for mtk_lap_1d_test.cc:



Functions

- int main ()

17.63.1 Function Documentation

17.63.1.1 int main ( )

Definition at line 156 of file mtk_lap_1d_test.cc.

17.64 mtk_lap_1d_test.cc

```
00001 #if __cplusplus == 201103L
00002
00003 #include <iostream>
00004
00005 #include "mtk.h"
00006
00007 void Test1() {
00008
00009   mtk::Tools::BeginTestNo(1);
00010
00011   mtk::Lap1D lap2;
00012
00013   bool info = lap2.ConstructLap1D();
00014
00015   if (!info) {
00016     std::cerr << "Mimetic lap (2nd order) could not be built." << std::endl;
00017   }
00018
00019   mtk::Tools::EndTestNo(1);
00020 }
00021
00022 void Test2() {
00023
00024   mtk::Tools::BeginTestNo(2);
00025
00026   mtk::Lap1D lap4;
00027
00028   bool info = lap4.ConstructLap1D(4);
00029
00030   if (!info) {
00031     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00032   }
00033
00034   mtk::Tools::EndTestNo(2);
00035 }
00036
00037 void Test3() {
00038
00039   mtk::Tools::BeginTestNo(3);
00040
00041   mtk::Lap1D lap6;
00042
00043   bool info = lap6.ConstructLap1D(6);
00044
00045   if (!info) {
00046     std::cerr << "Mimetic lap (6th order) could not be built." << std::endl;
00047   }
00048
00049   mtk::Tools::EndTestNo(3);
00050 }
00051
00052 void Test4() {
00053
00054   mtk::Tools::BeginTestNo(4);
00055
00056   mtk::Lap1D lap8;
00057
00058   bool info = lap8.ConstructLap1D(8);
00059
00060   if (!info) {
00061     std::cerr << "Mimetic lap (8th order) could not be built." << std::endl;
00062   }
00063
00064   mtk::Tools::EndTestNo(4);
00065 }
00066
00067 void Test5() {
00068
00069   mtk::Tools::BeginTestNo(5);
00070
```

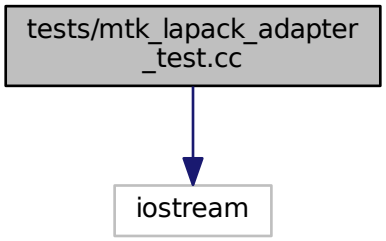
```
00071   mtk::Lap1D lap10;
00072
00073   bool info = lap10.ConstructLap1D(10);
00074
00075   if (!info) {
00076     std::cerr << "Mimetic lap (10th order) could not be built." << std::endl;
00077   }
00078
00079   mtk::Tools::EndTestNo(5);
00080 }
00081
00082 void Test6() {
00083
00084   mtk::Tools::BeginTestNo(6);
00085
00086   mtk::Lap1D lap12;
00087
00088   bool info = lap12.ConstructLap1D(12);
00089
00090   if (!info) {
00091     std::cerr << "Mimetic lap (12th order) could not be built." << std::endl;
00092   }
00093
00094   mtk::Tools::EndTestNo(6);
00095 }
00096
00097 void Test7() {
00098
00099   mtk::Tools::BeginTestNo(7);
00100
00101   mtk::Lap1D lap4;
00102
00103   bool info = lap4.ConstructLap1D(4);
00104
00105   if (!info) {
00106     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00107   }
00108
00109   std::cout << lap4 << std::endl;
00110   std::cout << std::endl;
00111
00112   mtk::Tools::EndTestNo(7);
00113 }
00114
00115 void Test8() {
00116
00117   mtk::Tools::BeginTestNo(8);
00118
00119   mtk::Lap1D lap4;
00120
00121   bool info = lap4.ConstructLap1D(4);
00122
00123   if (!info) {
00124     std::cerr << "Mimetic lap (4th order) could not be built." << std::endl;
00125   }
00126
00127   std::cout << lap4 << std::endl;
00128   std::cout << std::endl;
00129
00130   mtk::UniStgGrid1D aux(0.0, 1.0, 11);
00131
00132   mtk::DenseMatrix lap4_m(lap4.ReturnAsDenseMatrix(aux));
00133
00134   std::cout << lap4_m << std::endl;
00135   std::cout << std::endl;
00136
00137   mtk::Tools::EndTestNo(8);
00138 }
00139
00140 int main () {
00141
00142   std::cout << "Testing MTK 1D Laplacian" << std::endl;
00143
00144   Test1();
00145   Test2();
00146   Test3();
00147   Test4();
00148   Test5();
00149   Test6();
00150   Test7();
00151   Test8();
```

```
00152 }
00153
00154 #else
00155 #include <iostream>
00156 int main () {
00157   std::cout << "This code HAS to be compiled to support C++11." << std::endl;
00158   std::cout << "Exiting..." << std::endl;
00159 }
00160 #endif
```

17.65 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 ()

17.65.1 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.

17.65.2 Function Documentation

17.65.2.1 int main ( )

Definition at line 81 of file mtk_lapack_adapter_test.cc.

17.66 mtk_lapack_adapter_test.cc

```
00001
00010 /*
00011 Copyright (C) 2015, Computational Science Research Center, San Diego State
00012 University. All rights reserved.
00013
00014 Redistribution and use in source and binary forms, with or without modification,
00015 are permitted provided that the following conditions are met:
00016
00017 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00018 and a copy of the modified files should be reported once modifications are
00019 completed. Documentation related to said modifications should be included.
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 of source code must retain the above copyright notice, this
00025 list of conditions and the following disclaimer.
00026
00027 4. 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 5. Usage of the binary form on proprietary applications shall require explicit
00032 prior written permission from the the copyright holders.
00033
00034 6. Neither the name of the copyright holder nor the names of its contributors
00035 may be used to endorse or promote products derived from this software without
00036 specific prior written permission.
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00039 not infringe any patent, copyright, or any other intellectual property rights of
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00043
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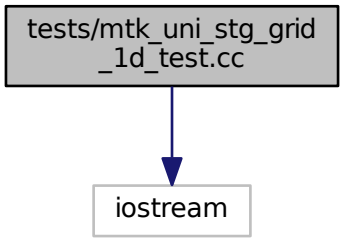
00045 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00046 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00047 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00048 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00049 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
00050 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00051 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00052 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00053 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00054 */
00055
00056 #if __cplusplus == 201103L
00057
00058 #include <iostream>
00059 #include <ctime>
00060
00061 #include "mtk.h"
00062
00063 void Test1() {
00064
00065   mtk::Tools::BeginTestNo(1);
00066
00067   mtk::Tools::EndTestNo(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
```

17.67 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 ()

17.67.1 Detailed Description

Author

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Definition in file mtk_uni_stg_grid_1d_test.cc.

17.67.2 Function Documentation

17.67.2.1 int main ( )

Definition at line 164 of file mtk_uni_stg_grid_1d_test.cc.

17.68 mtk_uni_stg_grid_1d_test.cc

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

```
00018
00019 2. Redistributions of source code must be done through direct
00020 downloads from the project's GitHub page: http://www.csrc.sdsu.edu/mtk
00021
00022 3. Redistributions of source code must retain the above copyright notice, this
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00049 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <ctime>
00058
00059 #include "mtk.h"
00060
00061 void Test1() {
00062
00063   mtk::Tools::BeginTestNo(1);
00064
00065   mtk::UniStgGrid1D gg;
00066
00067   std::cout << gg << std::endl;
00068
00069   mtk::Tools::EndTestNo(1);
00070 }
00071
00072 mtk::Real ScalarFieldOne(mtk::Real xx) {
00073
00074   return 2.0*xx;
00075 }
00076
00077 void Test2() {
00078
00079   mtk::Tools::BeginTestNo(2);
00080
00081   mtk::Real aa = 0.0;
00082   mtk::Real bb = 1.0;
00083
00084   int nn = 5;
00085
00086   mtk::UniStgGrid1D gg(aa, bb, nn);
00087
00088   std::cout << gg << std::endl;
00089
00090   gg.BindScalarField(ScalarFieldOne);
00091
00092   std::cout << gg << std::endl;
00093
00094   mtk::Tools::EndTestNo(2);
00095 }
00096
00097 void Test3() {
00098
```

```
00099   mtk::Tools::BeginTestNo(3);
00100
00101   mtk::Real aa = 0.0;
00102   mtk::Real bb = 1.0;
00103
00104   int nn = 5;
00105
00106   mtk::UniStgGrid1D gg(aa, bb, nn);
00107
00108   std::cout << gg << std::endl;
00109
00110   gg.BindScalarField(ScalarFieldOne);
00111
00112   std::cout << gg << std::endl;
00113
00114   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_03.dat", "x", "u(x)")) {
00115     std::cerr << "Error writing to file." << std::cerr;
00116   }
00117
00118   mtk::Tools::EndTestNo(3);
00119 }
00120
00121 mtk::Real VectorFieldXComponentOne(mtk::Real xx) {
00122
00123   return xx*xx;
00124 }
00125
00126 void Test4() {
00127
00128   mtk::Tools::BeginTestNo(4);
00129
00130   mtk::Real aa = 0.0;
00131   mtk::Real bb = 1.0;
00132
00133   int nn = 20;
00134
00135   mtk::UniStgGrid1D gg(aa, bb, nn, mtk::VECTOR);
00136
00137   std::cout << gg << std::endl;
00138
00139   gg.BindVectorField(VectorFieldXComponentOne);
00140
00141   std::cout << gg << std::endl;
00142
00143   if(!gg.WriteToFile("mtk_uni_stg_grid_1d_test_04.dat", "x", "v(x)")) {
00144     std::cerr << "Error writing to file." << std::cerr;
00145   }
00146
00147   mtk::Tools::EndTestNo(4);
00148 }
00149
00150 int main () {
00151
00152   std::cout << "Testing mtk::UniStgGrid1D class." << std::endl;
00153
00154   Test1();
00155   Test2();
00156   Test3();
00157   Test4();
00158 }
00159
00160 #else
00161 #include <iostream>
00162 using std::cout;
00163 using std::endl;
00164 int main () {
00165   cout << "This code HAS to be compiled with support for C++11." << endl;
00166   cout << "Exiting..." << endl;
00167 }
00168 #endif
```

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