

MMTK: MATLAB Wrappers for the Mimetic Methods Toolkit

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Chapter 1

Introduction

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

The **Mimetic Methods Toolkit (MTK)** is a C++ library for mimetic numerical methods. It is 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

Copyright (C) 2015, Computational Science Research Center, San Diego State University. All rights reserved.

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

1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu and a copy of the modified files should be reported once modifications are completed. Documentation related to said modifications should be included.
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.
5. Usage of the binary form on proprietary applications shall require explicit prior written permission from the the copyright holders.
6. Neither the name of the copyright holder nor the names of its contributors may be used to endorse or promote products derived from this software without specific prior written permission.

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

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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.

This collection of **MATLAB Wrappers for the MTK (MMTK)** allows developers to invoke the MTK from a MATLAB environment.

Finally, a collection of grid visualization routines that is compatible with these wrappers can be found in:

MATLAB Visualizers for Uniform Staggered Grids

2. Dependencies

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

```
```\n/home/ejspeiro/Libraries/\n```
```

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 and OS X:

1. MATLAB R2014a or greater - Available from: <http://www.mathworks.com/>
1. MTK - Available from: <http://csrc.sdsu.edu/mtk/>

## 3. Installation

The following instructions assume MATLAB R2014a or greater.

You have two options, either follow the instructions given, **expert install**, or use the provided **patch file**, **naive install**.

### EXPERT PART 1. CONFIGURATION OF THE MEX COMPILER.

From your MATLAB prompt, type:

```
```\n\nmex -setup C++
```

MEX configured to use 'g++' for C++ language compilation.
 Warning: The MATLAB C and Fortran API has changed to support MATLAB
 variables with more than $2^{32}-1$ elements. In the near future
 you will be required to update your code to utilize the
 new API. You can find more information about this at:

http://www.mathworks.com/help/matlab/matlab_external/upgrading-mex-files-to-use-64-bit-api.html.

'''

EXPERT PART 2. CONFIGURATION OF THE MEX COMPILER SETUP FILE.

The previous step creates the following file:

'''
 /home/ejspeiro/.matlab/R2014a/mex_C++_glnxa64.xml
 '''

The purpose of this section is to configure the MATLAB R2014a Mex compiler so that it can work with the latest C++ standard (C++11).

Please execute the following changes on the aforementioned file (line numbers may differ):

Lines 26 and 27:

'''
 CMDLINE1="\$CXX -std=c++11 -c \$DEFINES \$INCLUDE \$CXXFLAGS \$OPTIM \$SRC -o \$OBJ"
 CMDLINE2="\$LDXX -std=c++11 \$LD_FLAGS \$LDTYPE \$LINKOPTIM \$LINKEXPORT \$OBJ \$CXXLIBS \$LINKLIBS -o \$EXE"
 '''

Line 33:

'''
 CXXFLAGS="-std=c++11 -ansi -fexceptions -fPIC -fno-omit-frame-pointer -pthread"
 '''

Line 35 and 26:

```
```\nCXXOPTIMFLAGS="-std=c++11 -O -DNDEBUG"\nCXXDEBUGFLAGS="-std=c++11 -g"\n```\n
```

Line 38:

```
```\nLDXX="gfortran"\n```\n
```

Line 59:

```
```\nCXXFLAGS="-std=c++11 -ansi -pthread"\n```\n
```

#### NAIVE PART 1. CONFIGURATION OF THE MEX COMPILER.

From your MATLAB prompt, type:

```
```\n
```

```
mex -setup C++
```

MEX configured to use 'g++' for C++ language compilation.

Warning: The MATLAB C and Fortran API has changed to support MATLAB variables with more than $2^{32}-1$ elements. In the near future you will be required to update your code to utilize the new API. You can find more information about this at:

http://www.mathworks.com/help/matlab/matlab_external/upgrading-mex-files-to-use-64-bit-api.html.

```
```\n
```

---

## NAIVE PART 2. CONFIGURATION OF THE MEX COMPILER SETUP FILE.

```

'''
cd $HOME/.matlab/R2014a
chmod +w mex_C++_glnxa64.xml
patch < mex_C++_glnxa64.patch
chmod -w mex_C++_glnxa64.xml
'''
Exit terminal, and restart MATLAB. You can use C++11 to create MEX files now!

```

## PART 3: CONFIGURATION OF THE MAKEFILE.

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

```
'''
```

### \$ make help

Makefile for the MMTK.

Options are:

- all: builds the library, the tests, and examples.
- gendoc: generates the documentation for the library.
- - clean: cleans ALL the generated files.

```
'''
```

## PART 4. BUILD THE MMTK.

From your shell, at the base folder of the MMTK, just type:

```
```\nmake\n```
```

If successful you'll read:

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

## 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: When will the other flavors be ready?

A: Soon! I'm working on getting help on developing those.

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

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

Q: Do I need to generate the documentation myself?

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

## 5. Contact, Support, and Credits

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

Developers are members of:

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

Currently the developers are:

**Eduardo J. Sanchez, Ph.D. - [esanchez at mail dot sdsu dot edu](mailto:esanchez@mail.sdsu.edu) -**

- Jose E. Castillo, Ph.D. - [jcastillo at mail dot sdsu dot edu](mailto:jcastillo@mail.sdsu.edu)



- Guillermo F. Miranda, Ph.D. - unigrav at hotmail dot com
- Christopher P. Paolini, Ph.D. - paolini at engineering dot sdsu dot edu
- Angel Boada.
- Johnny Corbino.
- 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 -**

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

# File Index

### 8.1 File List

Here is a list of all files with brief descriptions:

<a href="#">Makefile.inc</a> . . . . .	26
examples/ <a href="#">Div1D.m</a> . . . . .	24
include/ <a href="#">mmtk.h</a>	
Includes the entire API . . . . .	25
mexsrc/ <a href="#">MMTKDiv1D.cc</a>	
MEX file for the Div1D class . . . . .	28
mexsrc/ <a href="#">MMTKDiv1D.m</a> . . . . .	31



## Chapter 9

# File Documentation

### 9.1 examples/Div1D.m File Reference

#### Variables

- close [all](#)
- [clc](#)
- [west](#) = 0.0
- [east](#)
- ss [num\\_cells](#) = 3\*[kk](#) - 1
- [div](#) = MMTKDiv1D([kk](#), [west](#), [east](#), [num\\_cells](#))
- [div](#) [kk](#)

#### 9.1.1 Variable Documentation

##### 9.1.1.1 clear all

Definition at line [21](#) of file [Div1D.m](#).

##### 9.1.1.2 clc

Definition at line [23](#) of file [Div1D.m](#).

##### 9.1.1.3 [div](#) = MMTKDiv1D([kk](#), [west](#), [east](#), [num\\_cells](#))

Definition at line [33](#) of file [Div1D.m](#).

##### 9.1.1.4 [east](#)

#### Initial value:

[west](#) = 1.0

[kk](#) = 2

[[ss](#), [mb](#), [qq](#)] = MMTKDiv1D([kk](#))

Definition at line 26 of file [Div1D.m](#).

#### 9.1.1.5 div kk

**Initial value:**

```
= 4
[ss, mb, qq] = MMTKDiv1D(kk)
```

Definition at line 36 of file [Div1D.m](#).

#### 9.1.1.6 ss mb qq num\_cells = 3\*kk - 1

Definition at line 32 of file [Div1D.m](#).

#### 9.1.1.7 west = 0.0

Definition at line 25 of file [Div1D.m](#).

## 9.2 Div1D.m

```
00001 % FUNCTION_NAME - Div1D
00002 % Creation of different high-order mimetic divergence operators with the MMTK.
00003 %
00004 % Other m-files required: None.
00005 % Subfunctions: The MMTK.
00006 % MAT-files required: None.
00007 %
00008 % See also: MMTKDiv1D.
00009 %
00010 % Author: Eduardo Sanchez, Ph.D.
00011 % Computational Science Research Center.
00012 % 5500 Campanile Drive, San Diego State University.
00013 % Email: esanchez at mail dot sdsu dot edu
00014 % Website: http://www-rohan.sdsu.edu/~sanche94/
00015 % 2015-09-10 14:18:35
00016
00017 %----- BEGIN CODE -----
00018
00019 addpath(' ../mexsrc ');
00020
00021 close all;
00022 clear all;
00023 clc;
00024
00025 west = 0.0;
00026 east = 1.0;
00027
00028 kk = 2;
00029 [ss, mb, qq] = MMTKDiv1D(kk);
00030 ss
00031
00032 num_cells = 3*kk - 1;
00033 div = MMTKDiv1D(kk, west, east, num_cells);
00034 div
00035
00036 kk = 4;
00037 [ss, mb, qq] = MMTKDiv1D(kk);
00038 ss
00039 mb
00040 qq
00041
00042 num_cells = 3*kk - 1;
00043 div = MMTKDiv1D(kk, west, east, num_cells);
00044 div
```

```
00045
00046 %----- END OF CODE -----
```

## 9.3 include/mmtk.h File Reference

Includes the entire API.

### 9.3.1 Detailed Description

This file contains the related documentation

#### Author

: Eduardo J. Sanchez: esanchez at mail dot sdsu dot edu

#### Warning

This file contains no logic for the MMTK. It has been created just for documentation purposes.

Definition in file [mmtk.h](#).

## 9.4 mmtk.h

```
00001
00013 /*
00014 Copyright (C) 2015, Computational Science Research Center, San Diego State
00015 University. All rights reserved.
00016
00017 Redistribution and use in source and binary forms, with or without modification,
00018 are permitted provided that the following conditions are met:
00019
00020 1. Modifications to source code should be reported to: esanchez@mail.sdsu.edu
00021 and a copy of the modified files should be reported once modifications are
00022 completed. 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
00026
00027 3. Redistributions of source code must retain the above copyright notice, this
00028 list of conditions and the following disclaimer.
00029
00030 4. Redistributions in binary form must reproduce the above copyright notice,
00031 this list of conditions and the following disclaimer in the documentation and/or
00032 other materials provided with the distribution.
00033
00034 5. Usage of the binary form on proprietary applications shall require explicit
00035 prior written permission from the the copyright holders.
00036
00037 6. Neither the name of the copyright holder nor the names of its contributors
00038 may be used to endorse or promote products derived from this software without
00039 specific prior written permission.
00040
00041 The copyright holders provide no reassurances that the source code provided does
00042 not infringe any patent, copyright, or any other intellectual property rights of
00043 third parties. The copyright holders disclaim any liability to any recipient for
00044 claims brought against recipient by any third party for infringement of that
00045 parties intellectual property rights.
00046
00047 THIS SOFTWARE IS PROVIDED BY THE COPYRIGHT HOLDERS AND CONTRIBUTORS "AS IS" AND
00048 ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO, THE IMPLIED
00049 WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
00050 DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT HOLDER OR CONTRIBUTORS BE LIABLE FOR
00051 ANY DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES
00052 (INCLUDING, BUT NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES;
```

```

00053 LOSS OF USE, DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON
00054 ANY THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
00055 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00056 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00057 */

```

## 9.5 Makefile.inc File Reference

## 9.6 Makefile.inc

```

00001 # Makefile setup file for MMTK.
00002
00003 SHELL := /bin/bash
00004
00005 # Please set the following variables up:
00006
00007 # 2. Absolute path to base directory of the MTK... where is the MTK?
00008 # _____
00009
00010 BASE = /home/ejspeiro/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: Uses OS X optimized solvers.
00018
00019 PLAT = LINUX
00020
00021 # Options are:
00022 # - SINGLE: Use 4 B floating point numbers.
00023 # - DOUBLE: Use 8 B floating point numbers.
00024
00025 PRECISION = DOUBLE
00026
00027 # 3. Optimized solvers and operations by means of ATLAS in Linux?
00028 # _____
00029
00030 # If you have selected OSX in step 1, then you don't need to worry about this.
00031
00032 # Options are ON xor OFF:
00033
00034 ATL_OPT = OFF
00035
00036 # 4. Paths to dependencies (header files for compiling).
00037 # _____
00038
00039 # GLPK include path (soon to go):
00040
00041 GLPK_INC = $(HOME)/Libraries/glpk-4.55/include
00042
00043 # Linux: If ATLAS optimization is ON, users should only provide the path to
00044 # ATLAS:
00045
00046 ATLAS_INC = $(HOME)/Libraries/ATLAS_3.8.4-CORE/include
00047
00048 # OS X: Do nothing.
00049
00050 # 5. Paths to dependencies (archive files for (static) linking).
00051 # _____
00052
00053 # GLPK linking path (soon to go):
00054
00055 GLPK_LIB = $(HOME)/Libraries/glpk-4.55/lib/libglpk.a
00056
00057 # If optimization is OFF, then provide the paths for:
00058
00059 BLAS_LIB = $(HOME)/Libraries/BLAS/libblas.a
00060 LAPACK_LIB = $(HOME)/Libraries/lapack-3.4.1/liblapack.a
00061
00062 # WARNING: Vendor libraries should be used whenever they are available.
00063
00064 # However, if optimization is ON, please provide the path the ATLAS' archive:
00065

```

```

00066 ATLAS_LIB = $(HOME)/Libraries/ATLAS_3.8.4-CORE/ATLAS_3.8.4-BUILD-Citadel/lib
00067
00068 # 6. Compiler and its flags.
00069 #
00070
00071 # Debug Level. Options are:
00072 # 0. NO debug at all NOR any run-time checks... be cautious!
00073 # 1. Verbose (execution messages) AND run-time checks.
00074 # 2. Level 1 plus intermediate scalar-valued results.
00075 # 3. Level 2 plus intermediate array-valued results.
00076
00077 DEBUG_LEVEL = 3
00078
00079 # Flags recommended for release code:
00080
00081 CCFLAGS = -O2
00082
00083 # Flags recommended for debugging code:
00084
00085 CCFLAGS =
00086
00087 # 7. Archiver, its flags, and ranlib:
00088 #
00089
00090 ARCH = ar
00091 ARCHFLAGS = cr
00092
00093 # If your system does not have "ranlib" then set: "RANLIB = echo":
00094
00095 RANLIB = echo
00096
00097 # But, if possible:
00098
00099 RANLIB = ranlib
00100
00101 # 8. Valgrind's memcheck options:
00102 #
00103
00104 MEMCHECK_OPTS = -v --tool=memcheck --leak-check=full --show-leak-kinds=all \
00105 --track-origins=yes --freelist-vol=20000000
00106
00107 # Done!
00108
00109 #
00110 #
00111 #
00112
00113 # MMTK-related.
00114 #
00115
00116 SRC = $(BASE)/src
00117 INCLUDE = $(BASE)/include
00118 LIB = $(BASE)/lib
00119 MTK_LIB = $(LIB)/libmtk.a
00120 TESTS = $(BASE)/tests
00121 EXAMPLES = $(BASE)/examples
00122
00123 # Compiling-related.
00124 #
00125
00126 CC = mex
00127
00128 CCFLAGS += -largeArrayDims -g
00129
00130 ifeq ($(PRECISION),DOUBLE)
00131 CCFLAGS += -DMTK_PRECISION_DOUBLE
00132 else
00133 CCFLAGS += -DMTK_PRECISION_SINGLE
00134 endif
00135
00136 CCFLAGS += -DMTK_DEBUG_LEVEL=$(DEBUG_LEVEL) -I$(INCLUDE)
00137
00138 # Only the GLPK is included because the other dependencies are coded in Fortran.
00139
00140 ifeq ($(ATL_OPT),ON)
00141 CCFLAGS += -I$(GLPK_INC) $(ATLAS_INC)
00142 else
00143 CCFLAGS += -I$(GLPK_INC)
00144 endif
00145
00146 # Linking-related.

```

```

00147 #
00148
00149 NOOPT_LIBS = $(LAPACK_LIB) $(GLPK_LIB) $(BLAS_LIB) -lstdc++ -lgfortran
00150
00151 OPT_LIBS = -L$(ATLAS_LIB) -latlas -llapack -lblas -lm -latlas \
00152 -lstdc++ -lgfortran
00153
00154 LIBS = $(MTK_LIB)
00155
00156 ifeq ($(PLAT),OSX)
00157 LIBS += -framework Accelerate $(GLPK_LIB)
00158 else
00159 ifeq ($(ATL_OPT),ON)
00160 LIBS += $(OPT_LIBS)
00161 else
00162 LIBS += $(NOOPT_LIBS)
00163 endif
00164 endif
00165
00166 # Documentation-related.
00167 #
00168
00169 DOCGEN = doxygen
00170 DOCFILENAME = doc_config.dxcf
00171 DOC = $(HOME)/Dropbox/MMTK/doc
00172 DOCFILE = $(HOME)/Dropbox/MMTK/$(DOCFILENAME)

```

## 9.7 mexsrc/MMTKDiv1D.cc File Reference

MEX file for the Div1D class.

### 9.7.1 Detailed Description

#### Author

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

Definition in file [MMTKDiv1D.cc](#).

## 9.8 MMTKDiv1D.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
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00050 (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF THIS
00051 SOFTWARE, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.
00052 */
00053
00054 #if __cplusplus == 201103L
00055
00056 #include <iostream>
00057 #include <iomanip>
00058 #include <cmath>
00059 #include <cstring>
00060
00061 #include "mex.h"
00062
00063 #include "mtk.h"
00064
00065 using namespace std;
00066
00067 static int MTKDiv1D(int order_accuracy,
00068 mtk::Real tau,
00069 mtk::Real *outS,
00070 mtk::Real *outM,
00071 mtk::Real *outQ);
00072
00073 static int MTKDiv1DReturnAsDenseMatrix(int order_accuracy,
00074 mtk::Real west_bndy_x,
00075 mtk::Real east_bndy_x,
00076 int num_cells,
00077 mtk::Real tau,
00078 mtk::Real *outMatrix);
00079
00080 void mexFunction(int nlhs, mxArray *plhs[], int nrhs, const mxArray *prhs[]) {
00081
00082 int order_accuracy; // kk inside MTK.
00083 int num_cells; // scaler to matrix size.
00084
00085 mtk::Real *outMatrix; // Where to place our output.
00086 mtk::Real *outS; // Output Stencil.
00087 mtk::Real *outQ; // Output Weights.
00088 mtk::Real *outM; // Output Mimetic Coefficients.
00089
00090 mtk::Real west_bndy_x; // Start of the Interval.
00091 mtk::Real east_bndy_x; // End of the Interval.
00092 mtk::Real tau; // Mimetic tolerance (optional).
00093
00094 if (nrhs >= 1 && nrhs <= 2) {
00095
00096 order_accuracy = mxGetScalar(prhs[0]);
00097
00098 if (nrhs == 1 && order_accuracy < mtk::kCriticalOrderAccuracyDiv) {
00099 tau = mtk::kDefaultMimeticThreshold;
00100 std::cout << "Default mimetic threshold set as " << tau << std::endl;
00101 }
00102 if (nrhs == 1 && order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00103 tau = mtk::kDefaultMimeticThreshold;
00104 std::cout << "Default mimetic threshold set as " << tau << std::endl;
00105 }
00106 if (nrhs == 2 && order_accuracy < mtk::kCriticalOrderAccuracyDiv) {
00107 tau = mxGetScalar(prhs[1]);
00108 std::cout << "Order of accuracy does not need mimetic threshold. If provided it will be ignored." <<
std::endl;
00109 }
00110 if (nrhs == 2 && order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00111 tau = mxGetScalar(prhs[1]);
00112 }
00113 if (nlhs != 3) {

```

```

00114 mexErrMsgIdAndTxt("MMTK:Div1D:nlhs","3 outputs are needed: S, M, Q.");
00115 }
00116 if (nlhs == 3) {
00117 // Stencil.
00118 plhs[0] = mxCreateDoubleMatrix((mwSize) 1,
00119 (mwSize) order_accuracy,
00120 mxREAL);
00121
00122 // Mimetic coefficients rows.
00123 plhs[1] = mxCreateDoubleMatrix((mwSize) (order_accuracy/2 - 1),
00124 (mwSize) (3*order_accuracy/2),
00125 mxREAL);
00126
00127 // Weights.
00128 plhs[2] = mxCreateDoubleMatrix((mwSize) 1,
00129 (mwSize) order_accuracy,
00130 mxREAL);
00131
00132 outS = mxGetPr(plhs[0]);
00133 outQ = mxGetPr(plhs[2]);
00134 outM = mxGetPr(plhs[1]);
00135
00136 MTKDiv1D(order_accuracy, tau, outS, outQ, outM);
00137 }
00138 } else {
00139 if (nrhs > 5) {
00140 mexErrMsgIdAndTxt("MMTK:Div1D:nrhs",
00141 "At most 5 inputs are permitted: (order, west, east, cells, tau).");
00142 }
00143 if (nrhs < 4) {
00144 mexErrMsgIdAndTxt("MMTK:Div1D:nrhs",
00145 "At least 4 inputs are required: (order, west, east, cells).");
00146 }
00147 if (nlhs != 1) {
00148 mexErrMsgIdAndTxt("MMTK:Div1D:nlhs","Only one output is needed.");
00149 }
00150 order_accuracy = mxGetScalar(prhs[0]);
00151 west_bndy_x = mxGetScalar(prhs[1]);
00152 east_bndy_x = mxGetScalar(prhs[2]);
00153 num_cells = mxGetScalar(prhs[3]);
00154
00155 if (num_cells < 3*order_accuracy - 1) {
00156 mexErrMsgIdAndTxt("MMTK:Div1D:nrhs", "Number of cells too small for required order.");
00157 }
00158 if (order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00159 std::cout << "Order of accuracy too high. Mimetic threshold will be applied." << std::endl;
00160 }
00161 if (nrhs == 5 && order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00162 tau = mxGetScalar(prhs[4]);
00163 }
00164 if (nrhs == 5 && order_accuracy < mtk::kCriticalOrderAccuracyDiv) {
00165 std::cout << "Order of accuracy does not need mimetic threshold. If provided it will be ignored." <<
00166 std::endl;
00167 tau = mxGetScalar(prhs[4]);
00168 }
00169 if (nrhs == 4 && order_accuracy >= mtk::kCriticalOrderAccuracyDiv) {
00170 //Default threshold, used only if order >= mtk::kCriticalOrderAccuracyDiv.
00171 tau = mtk::kDefaultMimeticThreshold;
00172 std::cout << "Default mimetic threshold set as" << tau << std::endl;
00173 }
00174
00175 plhs[0] = mxCreateDoubleMatrix((mwSize) (num_cells + 2),
00176 (mwSize) (num_cells + 1),
00177 mxREAL);
00178
00179 outMatrix = mxGetPr(plhs[0]);
00180
00181 MTKDiv1DReturnAsDenseMatrix(order_accuracy,
00182 west_bndy_x, east_bndy_x, num_cells,
00183 tau, outMatrix);
00184 }
00185 }
00186
00187 static int MTKDiv1D(int order_accuracy,
00188 mtk::Real tau,

```

```

00194 mtk::Real *outS,
00195 mtk::Real *outQ,
00196 mtk::Real *outM) {
00197
00198 mtk::Div1D div;
00199
00200 bool info = div.ConstructDiv1D(order_accuracy, tau);
00201
00202 if (!info) {
00203 std::cerr << "Mimetic div could not be built." << std::endl;
00204 }
00205
00206 int number_of_extra_rows = order_accuracy/2 - 1;
00207
00208 if (order_accuracy > mtk::kDefaultOrderAccuracy) {
00209 for(auto ii = 0; ii < order_accuracy; ++ii) {
00210 outS[ii] = div.coeffs_interior()[ii];
00211 outQ[ii] = div.weights_cbs()[ii];
00212 }
00213 mtk::DenseMatrix ee(div.mim_bndy());
00214
00215 ee.OrderColMajor();
00216
00217 for(auto ii = 0; ii < (3*order_accuracy/2)*number_of_extra_rows; ++ii) {
00218 outM[ii] = ee.data()[ii];
00219 }
00220 } else {
00221 for(auto ii = 0; ii < order_accuracy; ++ii) {
00222 outS[ii] = div.coeffs_interior()[ii];
00223 }
00224 }
00225 }
00226
00227 static int MTKDiv1DReturnAsDenseMatrix(int order_accuracy,
00228 mtk::Real west_bndy_x,
00229 mtk::Real east_bndy_x,
00230 int num_cells,
00231 mtk::Real tau,
00232 mtk::Real *outMatrix) {
00233
00234 int nn = num_cells + 2;
00235 int mm = num_cells + 1;
00236
00237 mtk::Div1D div;
00238
00239 bool info = div.ConstructDiv1D(order_accuracy, tau);
00240
00241 if (!info) {
00242 std::cerr << "Mimetic div could not be built." << std::endl;
00243 }
00244
00245 mtk::UniStgGrid1D grid(west_bndy_x, east_bndy_x, num_cells);
00246
00247 mtk::DenseMatrix divm(div.ReturnAsDenseMatrix(grid));
00248
00249 divm.OrderColMajor();
00250
00251 for(auto ii = 0; ii < mm*nn; ++ii) {
00252 outMatrix[ii] = divm.data()[ii];
00253 }
00254 }
00255
00256 #endif

```

## 9.9 mexsrc/MMTKDiv1D.m File Reference

### 9.10 MMTKDiv1D.m

```

00001 % MMTKDiv1D Create a mimetic one-dimensional divergence operator.
00002 %
00003 % div = MMTKDiv1D(k, w, e, n, tau) Returns the divergence order k as a n + 2
00004 % by n + 1 matrix, in the interval (w,e) with
00005 % discretized using n cells with the given
00006 % mimetic threshold tau (optional).
00007 %

```

```

00008 % [s, m, q] = MMTKDiv1D(k, tau) Returns the divergence order k as the
00009 % interior stencil s, mimetic coefficients m,
00010 % mimetic weights q and mimetic threshold tau
00011 % (optional).
00012 %
00013 % For more information, see
00014 %
00015 % Mimetic Discretization Methods.
00016 %

```

## 9.11 README.md File Reference

## 9.12 README.md

```

00001 # MATLAB wrappers for the Mimetic Methods Toolkit (MMTK)
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. The MTK can
00015 be found in:
00016
00017 [The Mimetic Methods Toolkit (MTK)](https://github.com/ejspeiro/MTK)
00018
00019 This collection of **MATLAB Wrappers for the MTK (MMTK)** allows developers to
00020 invoke the MTK from a MATLAB environment.
00021
00022 Finally, a collection of grid visualization routines that is compatible with
00023 these wrappers can be found in:
00024
00025 [MATLAB Visualizers for Uniform Staggered Grids](https://github.com/ejspeiro/UniStgGrid-Visualizers)
00026 _____
00027
00028 ## 2. Dependencies
00029
00030 This README assumes all of these dependencies are installed in the following
00031 folder:
00032
00033 ```
00034 $(HOME)/Libraries/
00035 ```
00036
00037 In this version, the MTK optionally uses ATLAS-optimized BLAS and LAPACK
00038 routines for the internal computation on some of the layers. However, ATLAS
00039 requires both BLAS and LAPACK in order to create their optimized distributions.
00040 Therefore, the following dependencies tree arises:
00041
00042 ### For Linux and OS X:
00043
00044 1. MATLAB R2014a or greater - Available from: http://www.mathworks.com/
00045
00046 1. MTK - Available from: http://csrc.sdsu.edu/mtk/
00047
00048 Plus all of the dependencies the MTK entails.
00049 _____
00050
00051 ## 3. Installation
00052
00053 The following instructions assume MATLAB R2014a or greater.
00054
00055 You have two options, either follow the instructions given, **expert install**,
00056 or use the provided **patch file**, **naive install**.
00057
00058 ### EXPERT PART 1. CONFIGURATION OF THE MEX COMPILER.
00059
00060 From your MATLAB prompt, type:
00061

```

```

00062 ```
00063 >> mex -setup C++
00064 MEX configured to use 'g++' for C++ language compilation.
00065 Warning: The MATLAB C and Fortran API has changed to support MATLAB
00066 variables with more than 2^32-1 elements. In the near future
00067 you will be required to update your code to utilize the
00068 new API. You can find more information about this at:
00069
00070 http://www.mathworks.com/help/matlab/matlab_external/upgrading-mex-files-to-use-
00071 64-bit-api.html.
00072 >>
00073 ```
00074
00075 ### EXPERT PART 2. CONFIGURATION OF THE MEX COMPILER SETUP FILE.
00076
00077 The previous step creates the following file:
00078
00079 ```
00080 $(HOME)/.matlab/R2014a/mex_C++_glnxa64.xml
00081 ```
00082
00083 The purpose of this section is to configure the MATLAB R2014a Mex compiler so
00084 that it can work with the latest C++ standard (C++11).
00085
00086 Please execute the following changes on the aforementioned file (line numbers
00087 may differ):
00088
00089 Lines 26 and 27:
00090
00091 ```
00092 CMDLINE1="$CXX -std=c++11 -c $DEFINES $INCLUDE $CXXFLAGS $OPTIM $SRC -o $OBJ"
00093 CMDLINE2="$LDXX -std=c++11 $LDLFLAGS $LDTYPE $LINKOPTIM $LINKEXPORT $OBJ $CXXLIBS $LINKLIBS -o $EXE"
00094 ```
00095
00096 Line 33:
00097
00098 ```
00099 CXXFLAGS="-std=c++11 -ansi -fexceptions -fPIC -fno-omit-frame-pointer -pthread"
00100 ```
00101
00102 Line 35 and 26:
00103
00104 ```
00105 CXXOPTIMFLAGS="-std=c++11 -O -DNDEBUG"
00106 CXXDEBUGFLAGS="-std=c++11 -g"
00107 ```
00108
00109 Line 38:
00110
00111 ```
00112 LDXX="gfortran"
00113 ```
00114
00115 Line 59:
00116
00117 ```
00118 CXXFLAGS="-std=c++11 -ansi -pthread"
00119 ```
00120
00121 ### NAIVE PART 1. CONFIGURATION OF THE MEX COMPILER.
00122
00123 From your MATLAB prompt, type:
00124
00125 ```
00126 >> mex -setup C++
00127 MEX configured to use 'g++' for C++ language compilation.
00128 Warning: The MATLAB C and Fortran API has changed to support MATLAB
00129 variables with more than 2^32-1 elements. In the near future
00130 you will be required to update your code to utilize the
00131 new API. You can find more information about this at:
00132
00133 http://www.mathworks.com/help/matlab/matlab_external/upgrading-mex-files-to-use-
00134 64-bit-api.html.
00135 >>
00136 ```
00137
00138 ### NAIVE PART 2. CONFIGURATION OF THE MEX COMPILER SETUP FILE.
00139
00140 ```
00141 cd $HOME/.matlab/R2014a
00142 chmod +w mex_C++_glnxa64.xml

```

```

00143 patch < mex_C++_glnxa64.patch
00144 chmod -w mex_C++_glnxa64.xml
00145 ```
00146 Exit terminal, and restart MATLAB. You can use C++ to create MEX files now!
00147
00148 ### PART 3: CONFIGURATION OF THE MAKEFILE.
00149
00150 The following steps are required the build and test the MTK. Please use the
00151 accompanying 'Makefile.inc' file, which should provide a solid template to
00152 start with. The following command provides help on the options for make:
00153
00154 ```
00155 $ make help
00156 -----
00157 Makefile for the MMTK.
00158
00159 Options are:
00160 - all: builds the library, the tests, and examples.
00161
00162 - gendoc: generates the documentation for the library.
00163
00164 - clean: cleans ALL the generated files.
00165 -----
00166 ```
00167
00168 ### PART 4. BUILD THE MMTK.
00169
00170 From your shell, at the base folder of the MMTK, just type:
00171
00172 ```
00173 make
00174 ```
00175
00176 If successful you'll read:
00177
00178 ```
00179 ----- Library created! Check in /home/ejspeiro/Dropbox/MTK/lib
00180 ```
00181
00182 And that is it.
00183
00184
00185 ## 4. Frequently Asked Questions
00186
00187 Q: Why haven't you guys implemented GBS to build the library?
00188 A: I'm on it as we speak! ;)
00189
00190 Q: When will the other flavors be ready?
00191 A: Soon! I'm working on getting help on developing those.
00192
00193 Q: Is there any main reference when it comes to the theory on Mimetic Methods?
00194 A: Yes! Check: http://www.csrc.sdsu.edu/mimetic-book
00195
00196 Q: Do I need to generate the documentation myself?
00197 A: You can if you want to... but if you DO NOT want to, just go to our website.
00198
00199
00200 ## 5. Contact, Support, and Credits
00201
00202 The MTK is developed by researchers and adjuncts to the
00203 [Computational Science Research Center (CSRC)] (http://www.csrc.sdsu.edu/)
00204 at [San Diego State University (SDSU)] (http://www.sdsu.edu/).
00205
00206 Developers are members of:
00207
00208 1. Mimetic Numerical Methods Research and Development Group.
00209 2. Computational Geoscience Research and Development Group.
00210 3. Ocean Modeling Research and Development Group.
00211
00212 Currently the developers are:
00213
00214 - **Eduardo J. Sanchez, Ph.D. - esanchez@mail.sdsu.edu - @ejspeiro
00215 - Jose E. Castillo, Ph.D. - jcastillo@mail.sdsu.edu
00216 - Guillermo F. Miranda, Ph.D. - unigrav@hotmail.com
00217 - Christopher P. Paolini, Ph.D. - paolini@engineering.sdsu.edu
00218 - Angel Boada.
00219 - Johnny Corbino.
00220 - Raul Vargas-Navarro.
00221
00222 Finally, please feel free to contact me with suggestions or corrections:
00223

```

```
00224 **Eduardo J. Sanchez, Ph.D. - esanchez at mail dot sdsu dot edu** - @ejspeiro
00225
00226 Thanks and happy coding!
```

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