LaMEM
Lithospheric And Mantle Evolution Model

- Developers documentation -

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1 Introduction

This is an attempt to improve the documentation of LaMEM. Of course, nobody likes writing documentations. On the other hand, everybody commits small descriptions of latest updates to the version control system. However, from my perspective, these descriptions get lost very soon in the history of changes. Maybe we can simply copy and paste these short descriptions into this document too.

1.1 In a nutshell

To reduce efforts, parts of this manual, such as the code section (sec. 10) can be created automatically. All you need to do is

```
make doc
```

This will invoke a shell script that collects header information of all source files (`*.c`) stored in `/src` and `/src/fdstag/`. Everything written in any commented part within the following flags will be interpreted as LaTeX and will be appended to this file.

*.c file

```
/*
...
#START_DOC#
Your latex style documentation including formulas
#END_DOC#
...
*/
```

Requirements:

- LaTeX installation (TexLive 2013, see 1.2,1.3,1.4)
- Do you already have a installation? To find your installation, type:

  ```
  which pdflatex
  which bibtex
  ```

  Make sure it's the current version.
- Modify paths of LaTeX installation in `Makefile.in`:

  Makefile.in

  ```
  ...
  PDFLATEX = /usr/local/texlive/2013/bin/x86_64-darwin/pdflatex
  BIBTEX = /usr/local/texlive/2013/bin/x86_64-darwin/bibtex
  ...
  ```

1.2 Install LaTeX on Mac

Visit http://www.tug.org/mactex/ and install MacTeX.pkg using your mouse and drag & drop.

1.3 Install LaTeX on Mac (MacPorts)

```
sudo port install texlive
```

See http://www.macports.org/.

1.4 Install LaTeX on Ubuntu

```
sudo apt-get install texlive
```

See http://wiki.ubuntuusers.de/Tex_Live.

2 How to contribute to this document

- Between #START_DOC# and #END_DOC# you can write anything with LaTeX code (formulas, items, ...).
- Underscores cause problems. Since many functionnames contain underscores I propose the following **standard**: \lamemfunction{...} . The macro makes use of the package cprotect and introduces a subsubsection with the functionname.

  ```
  \lamemfunction{\verb- function_name1 -}
  Description1
  \lamemfunction{\verb- function_name2 -}
  Description2
  ```

- For anything else that contains underscores please use the verbatim environment

  ```
  \verb-text_with_underscores-
  ```

- Include PATHs of pdflatex and bibtex to Makefile.in (use TexLive 2013 on Mac)
- Citations: (Balay et al., 2012b) or Balay et al. (2012a)
- Figures: **No** raster graphics such as bitmaps, jpgs, etc.. Preferably scalable vector graphics (*.svg) should be used, it's *.xml code, so SVN can track the changes. You can use inkscape, illustrator, etc. to create your *.svg files.

3 Installation

3.1 MPI with valgrind support on Mac OS

```
./configure \
CC=wcc \
CXX=wc++ \
F77=wfc \
FC=wfc \
CPPFLAGS='-I/opt/valgrind/include/valgrind' \
--prefix=/opt/mpi/mpich2-debug \
--enable-f77 \
--enable-fc \
--enable-cxx \
--enable-threads=runtime \
--enable-g=dbg,mem,meminit \
--enable-debuginfo \
--enable-fast=none \
--with-thread-package=pthreads
```

3.2 Petsc with valgrind support on Mac OS

```
./configure \
--prefix=/opt/petsc/petsc-3.3-p2-int32-debug \
--download-f-blas-lapack=1 \
--with-debugging=1 \
--with-valgrind=1 \
--with-valgrind-dir=/opt/valgrind \
--COPTFLAGS="-g -O0" \
--FOPTFLAGS="-g -O0" \
--CXXOPTFLAGS="-g -O0" \
--with-large-file-io=1 \
--with-cc=mpicc \
--with-cxx=mpicxx \
--with-fc=mpif90 \
--download-ml=1 \
--download-hypre=1 \
--download-blacs=1 \
--download-scalapack=1 \
--download-metis=1 \
--download-parmetis=1 \
--download-mumps=1 \
--download-superlu_dist=1
```

4 Debugging

4.1 Valgrind

Use the script `ValgrindCheck.sh` in `/doc/valgrind/` to test your LaMEM Version for memory leaks.

- It's a script to launch parallel MPI applications on Linux under valgrind with MPI wrappers.
- Invocation pattern:

  ```
  ValgrindCheck.sh num_proc "exec_path prog_args" outfile_name
  ```

- All errors and screen output will be redirected to the file: `outfile_name.out`
- Valgrind errors & warnings will be written to a separate file for each MPI task: `outfile_name.pid.xml` (pid - system process ID of MPI task, assigned automatically)
- To visualize memory check summary in human readable format use Valkyrie GUI.

4.2 Parallel debugger: ddt on gaia

5 General structure

This a good place for a general callgraph etc.

6 Physics

$$\frac{\partial \sigma'_{ij}}{\partial x_j} - \frac{\partial P}{\partial x_i} + \rho g_i = 0 \tag{1}$$

$$\nabla \cdot \vec{v} = 0 \tag{2}$$

$$\sigma'_{ij} = 2\eta \dot{\epsilon}_{ij}, \tag{3}$$

7 Numerical implementation

8 Solvers

9 Output

9.1 Formats

10 Code

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10.19 File: LaMEMVelPressureDA_Q2PM1.c

10.20 File: LaMEM_AnalyticalSolutions.c

10.21 File: LaMEM_FE_ErosionCode.c

10.22 File: LaMEM_Initialize.c

10.23 File: LaMEM_Particles.c

10.24 File: LaMEM_Temperature.c

10.25 File: Material.c

Material.c, contains the following subroutines:

10.25.1 Function: `SetMaterialProperties`

Hardcoded setting of material properties

10.25.2 Function: `ComputeEffectiveViscosity`

Computes Frank Kamenetskii effective viscosity

10.25.3 Function: `ComputePointWiseProperties`

Compute properties such as velocity, strainrates, pressures etc. at a local point, with given element coordinates

10.25.4 Function: `LaMEMSetMaterialDataMemoryFromArray_New`

Computes Frank Kamenetskii effective viscosity ....

$$A = b \cdot c + 23.4 - 45.9$$

10.26 File: `Mesh.c`

10.27 File: `NonDimensionalisation.c`

10.28 File: `Output.c`

10.29 File: `ParaViewOutput.c`

10.30 File: `Parsing.c`

10.31 File: `Quadrature.c`

10.32 File: `Solvers.c`

This is a test for an equation.

$$\mathbf{A} \cdot \vec{x} = \vec{b} \tag{4}$$

10.33 **File:** StokesOperators.c

10.34 **File:** Utils.c

10.35 **File:** JacRes.c

10.36 **File:** advect.c

10.37 **File:** constEq.c

10.38 **File:** dfzero.c

10.39 **File:** fdstag.c

10.40 **File:** interface.c

10.41 **File:** interpolate.c

10.42 **File:** paraViewOutBin.c

References

Satish Balay, Jed Brown, , Kris Buschelman, Victor Eijkhout, William D. Gropp, Dinesh Kaushik, Matthew G. Knepley, Lois Curfman McInnes, Barry F. Smith, and Hong Zhang. PETSc users manual. Technical Report ANL-95/11 - Revision 3.3, Argonne National Laboratory, 2012a.

Satish Balay, Jed Brown, Kris Buschelman, William D. Gropp, Dinesh Kaushik, Matthew G. Knepley, Lois Curfman McInnes, Barry F. Smith, and Hong Zhang. PETSc Web page, 2012b. http://www.mcs.anl.gov/petsc.