



deal.II Users and Developers Training

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Goals

- How to use deal.II for Finite Element computations
- Refresh numerical PDE knowledge
- Also:
 - Software best practices
 - C++, Debugging, IDEs, Visualization
 - Parallel computations with MPI

Schedule

	Monday	Tuesday	Wednesday	Thursday
9:30 – 10:45	Introduction	Dimension Independence	Higher Order Mappings	Parallel Computing
11:15 – 12:30	First Steps	Computing Errors	Embedded Surfaces	MPI demo
14:00 – 15:15	Basics of FEM	Adaptive Refinement	Systems of PDEs	Exercises
15:45 – 17:00	Solving Poisson's eqn	Exercises	Exercises	Exercises

- See <http://indico.ictp.it/event/7751/other-view?view=ictp timetable> Green = in lecture room (tentative)
- Today:
 - What is deal.II?
 - Compiling, using an IDE
 - Overview about FEM
 - Basic tutorials (create mesh, solve Poisson's equation, visualization)
- Tuesday:
 - Finite Element Analysis (refinement, computing errors)
- Wednesday/Thursday:
 - Advanced topics
 - Time for projects

The plan

- Slides, some lectures on blackboard
- Many live demonstrations
- Exercises:
 - Work in groups of two!
 - Ask questions!
- Projects:
 - Required for MHPC students
 - Groups of two

Resources

- <http://indico.ictp.it/event/7751/overview>
 - Schedule, Rooms, etc.
- <http://dealii.org>
 - Manual
 - Tutorial steps
 - Tutorial videos
- On your machine: folder `/scratch/smr1909/`
 - Slides
 - Example programs
 - Exercises
 - Other files

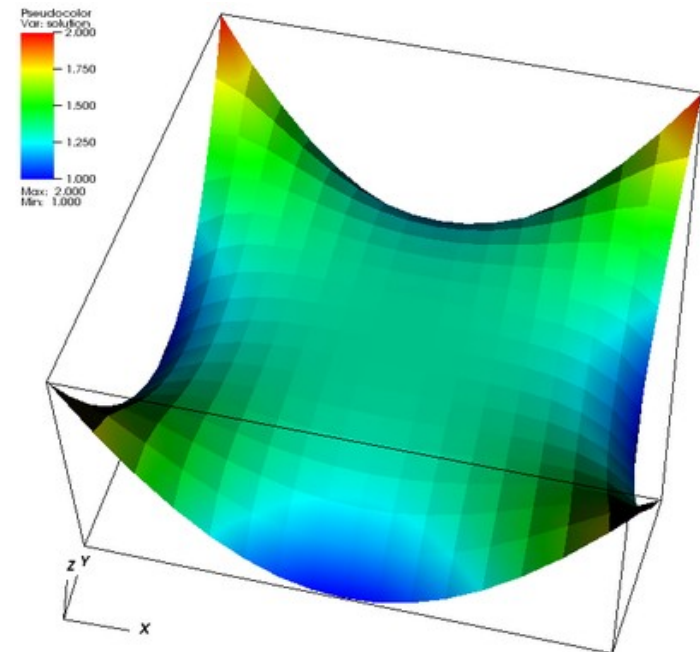
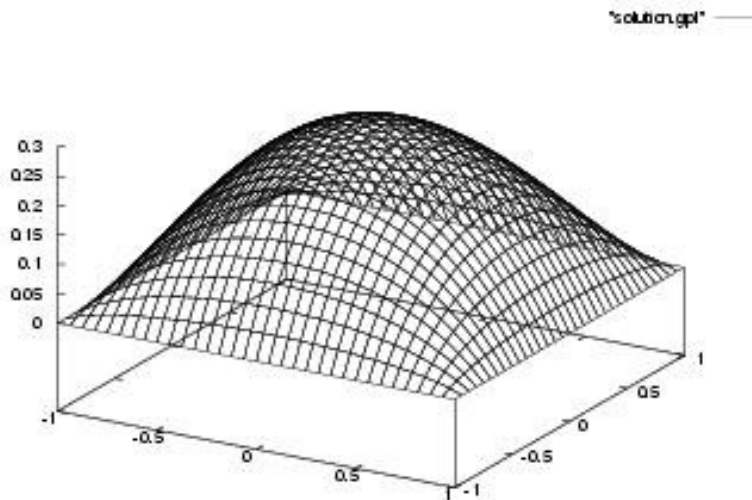
Finite Element Method

- Solve partial differential equations numerically

- Example:

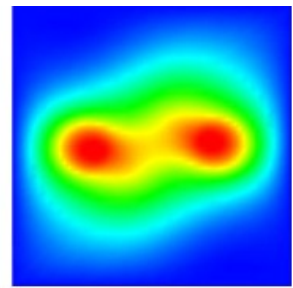
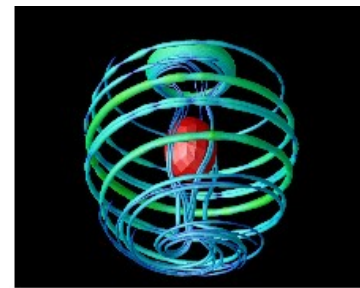
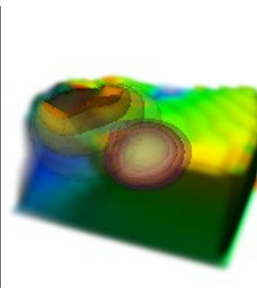
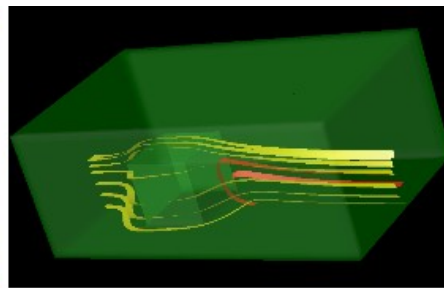
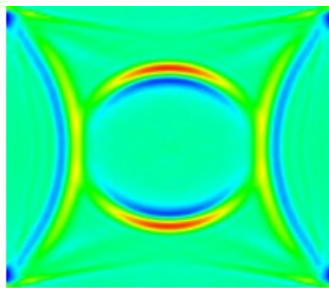
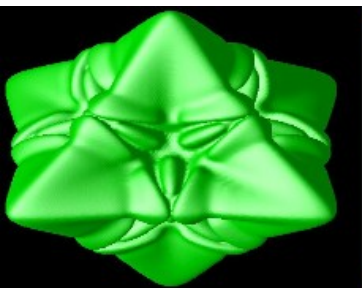
$$\begin{aligned} -\Delta u &= f \\ u &= 0 \end{aligned}$$

$$\begin{aligned} &\text{in } \Omega, \\ &\text{on } \partial\Omega. \end{aligned}$$



deal.II

- “A Finite Element **D**ifferential **E**quations **A**nalysis **L**ibrary”
- Open source, c++ library
- I am one of the four maintainers
- One of the most widely used libraries:
 - 800+ papers using and citing deal.II
 - ~600 downloads/month
 - 100+ people have contributed in the past 15 years
 - ~600,000 lines of code
 - 10,000+ pages of documentation
- Website: www.dealii.org



Features

- 1d, 2d, 3d computations, adaptive mesh refinement (on quads/hexes only)
- Finite element types:
 - Continuous and DG Lagrangian elements
 - Higher order elements, hp adaptivity
 - Raviart-Thomas, Nedelec, ...
 - And arbitrary combinations
- PDEs on surfaces embedded in higher dimensions

Features, part II

- Linear Algebra
 - Own sparse and dense library
 - Interfaces to PETSc, Trilinos, UMFPACK, BLAS, ..
- Parallelization
 - Laptop to supercomputers
 - Multi-threading on multi-core machines
 - MPI: 64,000+ processors
- Output in many visualization file formats

Development of deal.II

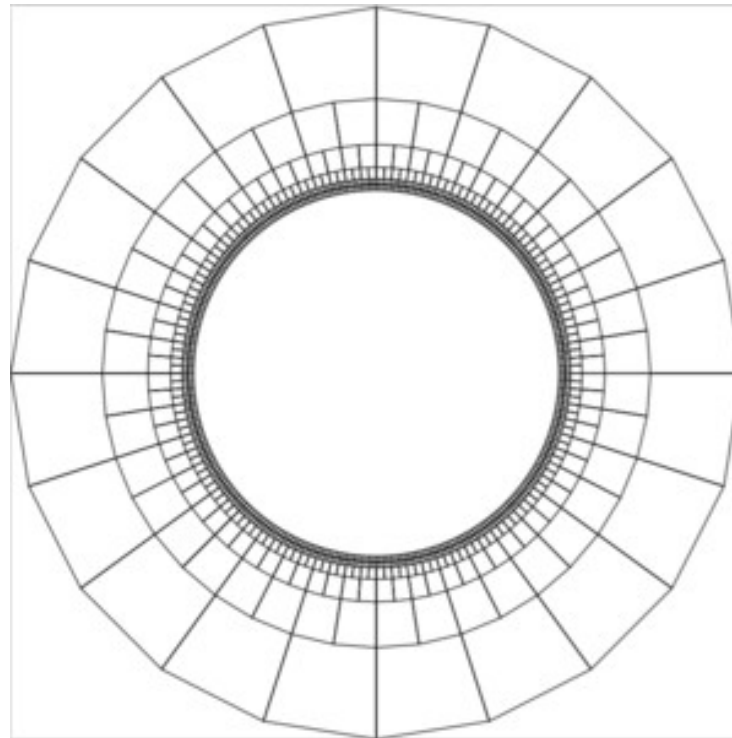
- Professional-level development style
- Development in the open, repository on github.com
- Mailing lists for users and developers
- Test suite with 6,000+ tests after every change
- Platform support:
 - Linux/Unix
 - Mac
 - Windows
- Hope to see you on github.com or the mailing list!

Lab Setup

- deal.II and all required dependencies are already installed at
 `/scratch/smr2909/`
- (Demo, show lab01.pdf and run included step-1)

Lab 1 (step-1)

- See lab01.pdf
- Topic: creating meshes



Running examples

- In short:

```
cd examples/step-1  
cmake .  
make run
```

- cmake:

- Detect configuration, only needs to be run once!
- Input: CMakeLists.txt
- Output: Makefile, (other files like CMakeCache.txt)

- make:

- Code compilation
- Tool to execute commands in Makefile, do every time you change your code
- Input: step-1.cc, Makefile
- Output: step-1 (the binary executable file)

- Run your program with

```
./step-1
```

- Or (compile and run):

```
make run
```

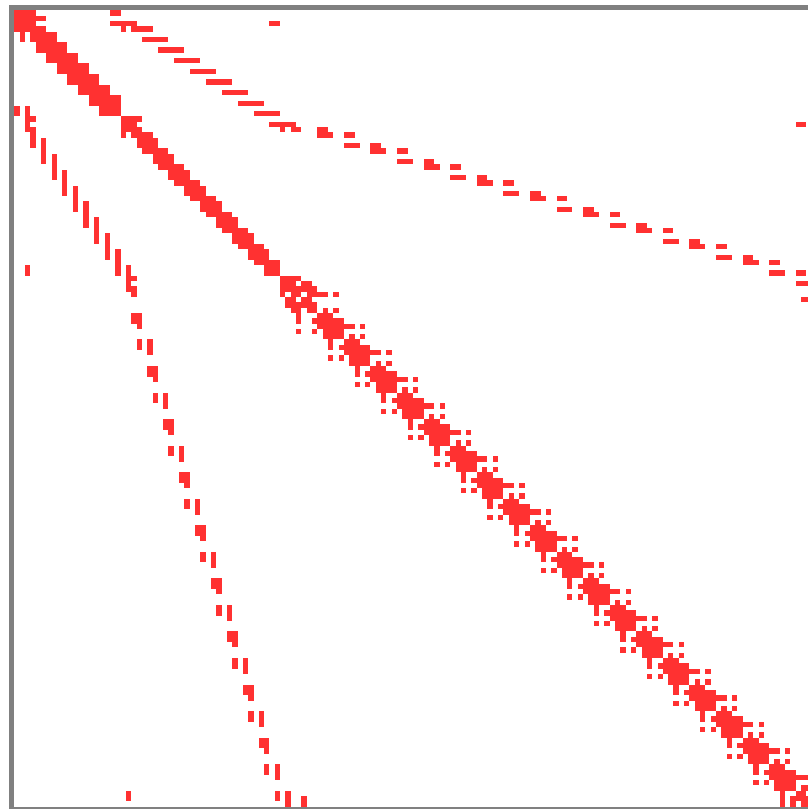
- Open in qtcreator IDE:

```
qtcreator .
```

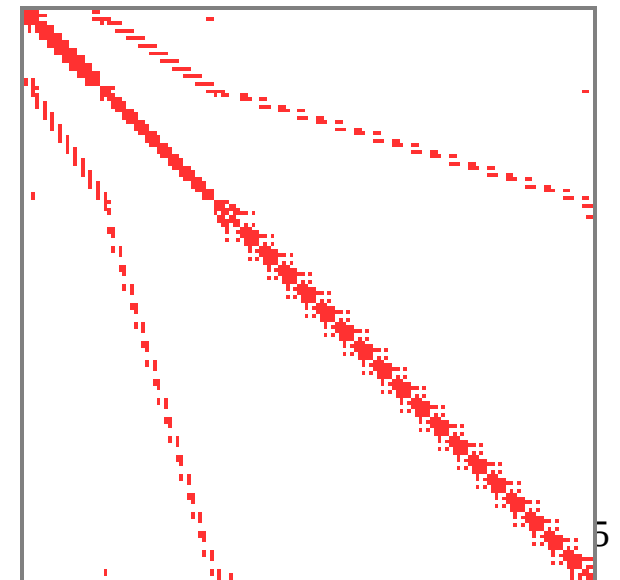
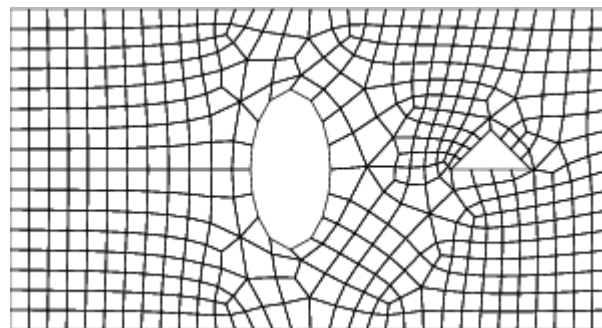
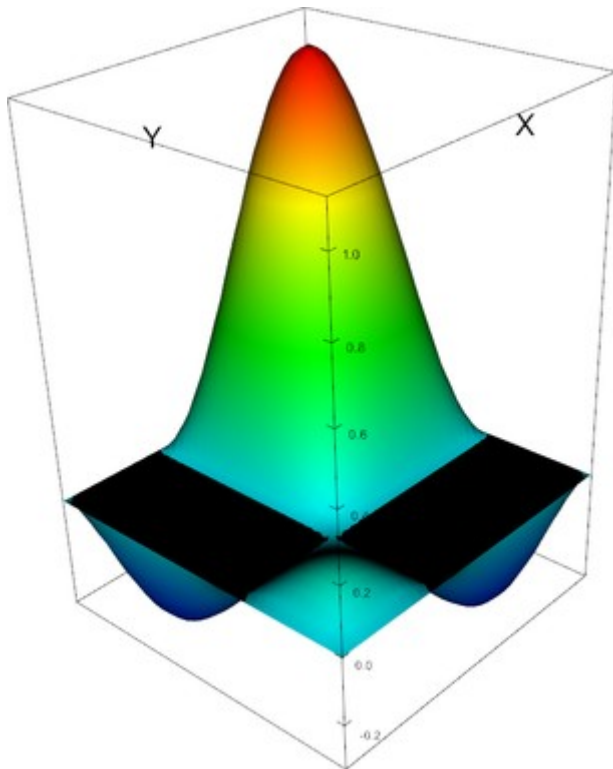
- Learn to use an IDE! (not vim, emacs, ...)
- Copy into home directory required!
- [Demo the above and open project in qtcreator]

Lab 2 (step-2)

- See lab02.pdf
- Topic: sparsity patterns of matrices



Finite Element Assembly



Lab 3 (step-3)

- See lab03.pdf
- Topic: solving Poisson's equation

