Finite element methods in scientific computing

Wolfgang Bangerth, Colorado State University

Lecture 2:

A real short overview of deal.II

deal.II

Deal.II is a finite element library. It provides:

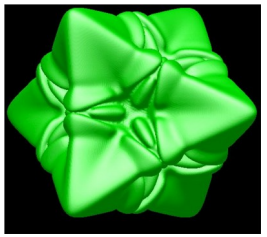
- Meshes
- Finite elements, quadrature,
- Linear algebra
- Most everything you will ever need when writing a finite element code

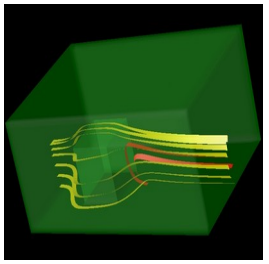
On the web at

http://www.dealii.org/

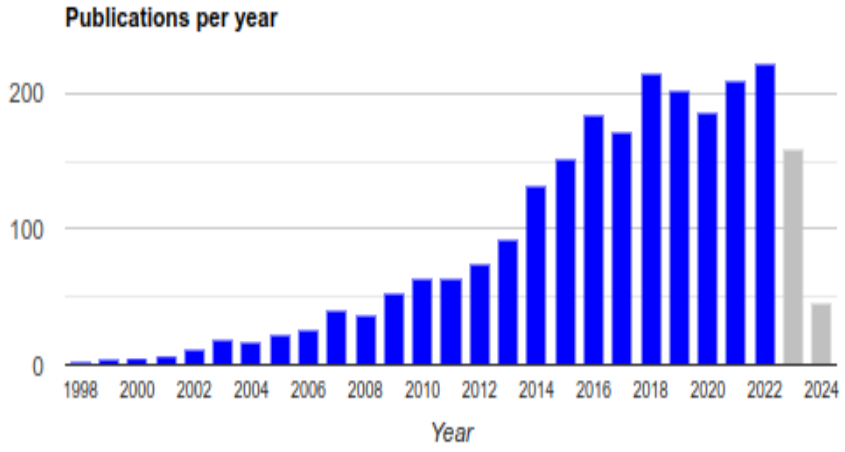
deal.II

deal.II is probably the largest FEM library:





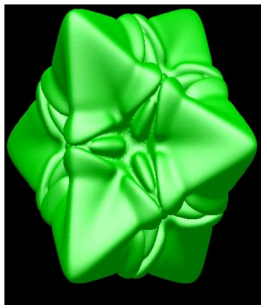
- Presently ~1,400,000 lines of C++ code
- 10,000 pages of documentation
- 80+ tutorial programs
- Fairly widely distributed:
  12,000+ downloads in 2018
- 220 publications in 2022,
  2400+ overall, that use it
- Used in teaching at a number
  of universities
- 2007 Wilkinson prize.

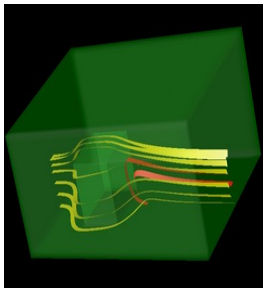


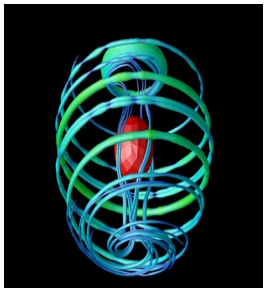
What's in deal.II

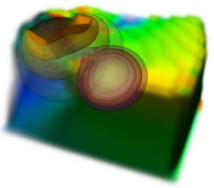
Meshes and elements:

- Supports adaptive meshes in 1d, 2d, and 3d
- Easy ways to adapt meshes: Standard refinement indicators already built in
- Many standard finite element types (continuous, discontinuous, mixed, Raviart-Thomas, ...)
- Low and high order elements
- Full support for multi-component problems





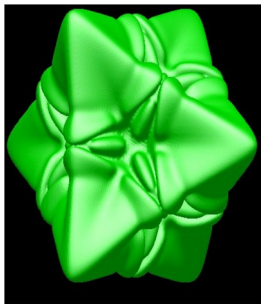




What's in deal.II

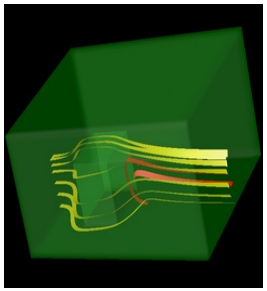
Linear algebra in deal.II:

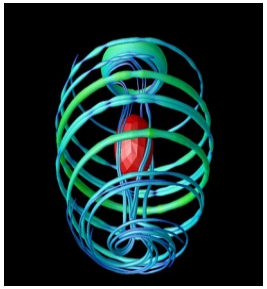
- Has its own sub-library for dense + sparse linear algebra
- Interfaces to PETSC, Trilinos, UMFPACK



Pre- and postprocessing:

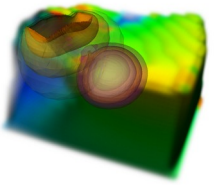
- Can read most mesh formats
- Can write almost any visualization file format





Parallelization:

- Uses threads and tasks on multicore machines
- Uses MPI, up to 300,000+ processors



What deal.II is used for

Apparently any PDE can be solved with deal.II.

In a typical year, papers are published that simulate:

- Biomedical imaging
- Heart muscle fibers

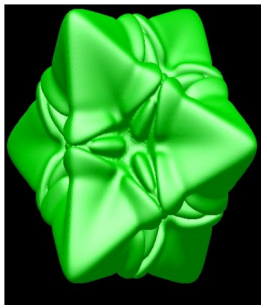
- Microfluidics
- Oil reservoir flow
- Fuel cells
- Aerodynamics

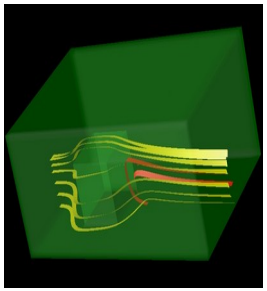
- Quantum mechanics
- Neutron transport

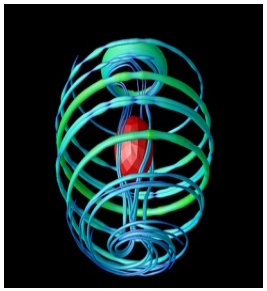
- Numerical methods research

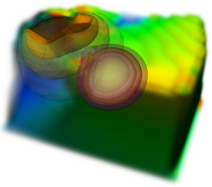
- Fracture mechanics
- Damage models
- Sedimentation
- Biomechanics
- Root growth of plants
- Solidification of alloys
- Glacier mechanics

- Deterioration of statues due to air pollution





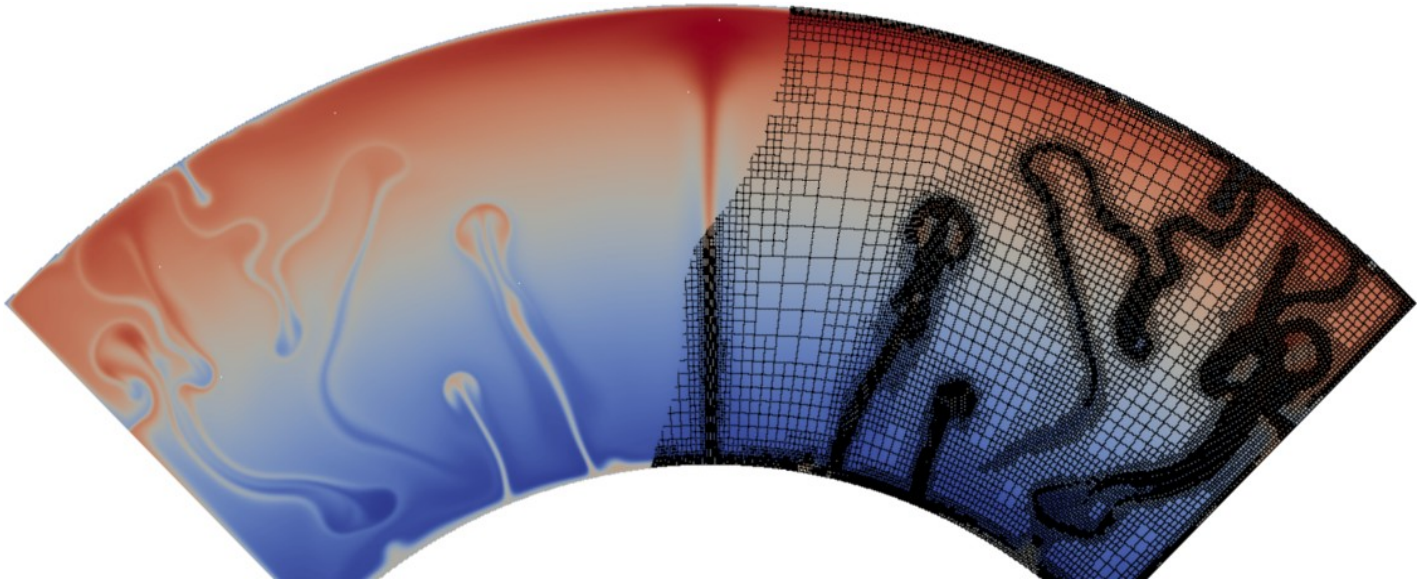




What deal.II is used for

Example: The mantle convection code ASPECT

http://aspect.dealii.org/



Methods:

- 2d, 3d, adaptive meshes, multigrid solvers
- Higher order finite elements
- Fully parallel

How deal.II is developed

Development:

- ~10 core developers (in Germany, Sweden, Canada, Italy, US)
- ~30 occasional contributors (around the world)
- 350+ people have contributed over the past 25 years

- ~5,000 lines of new code per month

deal.II is a typical open source project:

- People primarily develop what they need
- Open culture:
  – All development happens in the open
  – We (really) welcome everyone's contributions!

How deal.II is developed

Professional-level software management:

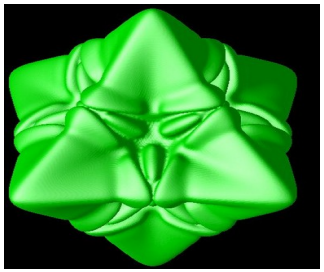
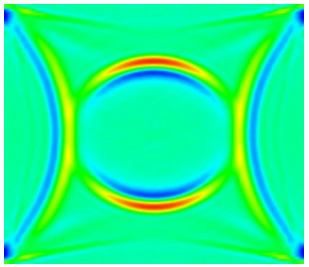
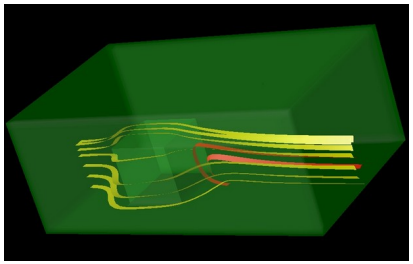
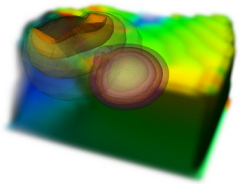
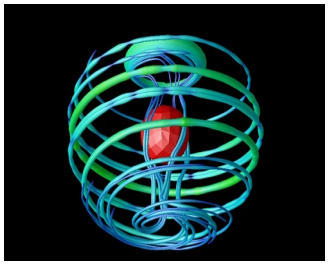
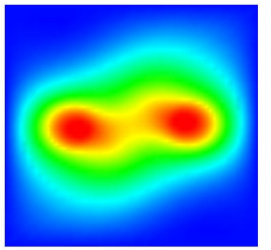
- Globally accessible repository: *http://github.com/dealii/dealii*
- Mailing lists with significant volume
  – for user questions
  – for developer discussions
- ~13,000 tests run after every change
- Multi-platform build systems
  – Linux/Unix
  – Mac OS X
  – Windows
- Web sites tracking changes, tests, builds, ...

Conclusions

- **Mission:**
  To provide everything that is needed in finite element computations.

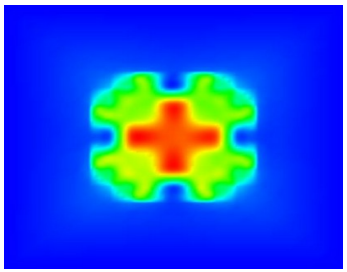
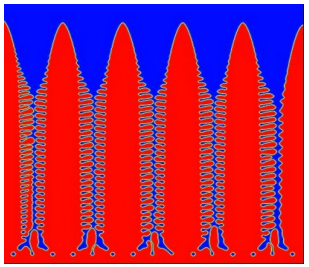
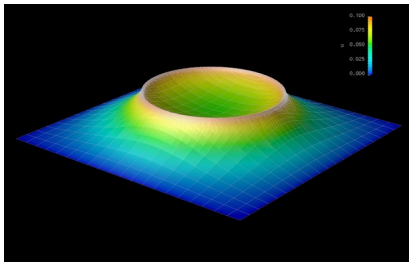
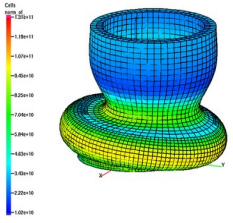
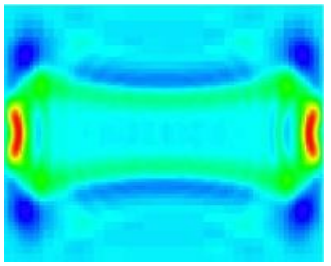
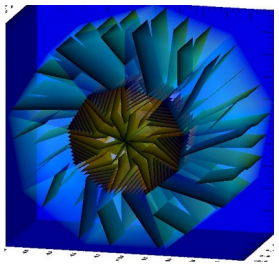
- **Development:**
  As an open source project
  As an inviting community to all who want to contribute
  As professional-grade software to users

On the web

Visit the deal.II library:

http://www.dealii.org/

Finite element methods in scientific computing

Wolfgang Bangerth, Colorado State University