FEniCS Course

Overview

Contributors
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fenics project

Course outline

L00 Introduction to FEM

L01 Introduction to FEniCS

L02 Static linear PDEs

L03 Static nonlinear PDEs

L04 Time-dependent PDEs

L05 Happy hacking: Tools, tips and coding practices

L06 Static hyperelasticity

L07 Dynamic hyperelasticity

L08 The Stokes problem

L09 Incompressible Navier–Stokes

L10 Discontinuous Galerkin methods for elliptic equations

L11 A posteriori error estimates and adaptivity

Lectures can be downloaded from

`http://fenicsproject.org/pub/course/`

Key distinguishing features

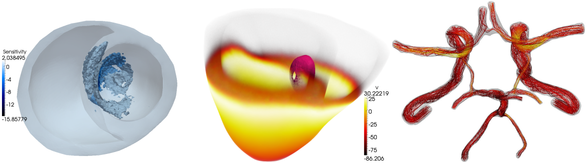
The FEniCS Project is a collection of open-source software components aimed at the numerical solution of partial differential equations using finite element methods

- FEniCS (Python/C++) code is quick to write and easy to read
- 'Any' finite element formulation of 'any' partial differential equation can be coded
- Automated code generation is heavily used under the hood to create efficient, specialized, low-level code
- Performance – implicit problems with over 12 000 000 000 degrees of freedom can be solved in a couple of minutes

http://fenicsproject.org/

FEniCS has been used for a wide range of equations and applications

Reaction-diffusion equations; Stokes with or without nonlinear viscosity; compressible and incompressible Navier–Stokes; RANS turbulence models; shallow water equations; Bidomain equations; nonlinear and linear elasticity; nonlinear and linear viscoelasticity; Schrödinger; Biot's equations for porous media, fracture mechanics, electromagnetism, liquid crystals including liquid crystal elastomers, combustion, ... and coupled systems of the above, ...



for simulating blood flow, computing calcium release in cardic tissue, computing the cardiac potential in the heart, simulating mantle convection, simulating melting ice sheets, computing the optimal placement of tidal turbines, simulating and reconstructing tsunamis, simulating the flow of cerebrospinal fluid and the deformation of the spinal cord, simulating waveguides, ...

Hello World in FEniCS: problem formulation

Poisson's equation

$$
\begin{aligned}
-\Delta u &= f \quad \text{in } \Omega \\
u &= 0 \quad \text{on } \partial\Omega
\end{aligned}
$$

Finite element formulation

Find $u \in V$ such that

$$
\underbrace{\int_\Omega \nabla u \cdot \nabla v \,\mathrm{d}x}_{a(u,v)} = \underbrace{\int_\Omega f\, v \,\mathrm{d}x}_{L(v)} \quad \forall\, v \in V
$$

Hello World in FEniCS: implementation

Python code

```
from fenics import *

mesh = UnitSquareMesh(32, 32)

V = FunctionSpace(mesh, "Lagrange", 1)
u = TrialFunction(V)
v = TestFunction(V)
f = Expression("x[0]*x[1]", degree=2)

a = dot(grad(u), grad(v))*dx
L = f*v*dx

bc = DirichletBC(V, 0.0, DomainBoundary())

u = Function(V)
solve(a == L, u, bc)
plot(u)
```

Basic API

- `Mesh`, `Vertex`, `Edge`, `Face`, `Facet`, `Cell`
- `FiniteElement`, `FunctionSpace`
- `TrialFunction`, `TestFunction`, `Function`
- `grad()`, `curl()`, `div()`, ...
- `Matrix`, `Vector`, `KrylovSolver`, `LUSolver`
- `assemble()`, `solve()`, `plot()`

- Python interface generated semi-automatically by SWIG
- C++ and Python interfaces almost identical

Three survival advices

Use the right Python tools

Explore the documentation

Ask, report and request

FEniCS PROJECT

About Download Documentation Applications Contributing Citing Support

Documentation for FEniCS 1.3.0

Our documentation includes a book, a collection of documented demo programs, and complete references for the FEniCS application programming interface (API). Note that the FEniCS API is documented separately for each FEniCS component. The most important interfaces are those of the C++/Python problem solving environment *DOLFIN* and the form language *UFL*.

(*This page accesses the FEniCS 1.3.0 documentation. Not the version you are looking for? See all versions.*)

The FEniCS Tutorial

A good starting point for new users is the *FEniCS Tutorial*. The tutorial will help you get quickly up and running with solving differential equations in FEniCS. The tutorial focuses exclusively on the FEniCS Python interface, since this is the simplest approach to exploring FEniCS for beginners.

The FEniCS Book

The FEniCS Book, Automated Solution of Differential Equations by the Finite Element Method, is a comprehensive (700 pages) book documenting the mathematical methodology behind the FEniCS Project and the software developed as part of the FEniCS Project. The FEniCS Tutorial is included as the opening chapter of the FEniCS Book.

The FEniCS Manual

The FEniCS Manual is a 200-page excerpt from the FEniCS Book, including the FEniCS Tutorial, an introduction to the finite element method and documentation of DOLFIN and UFL.

Additional Documentation

Mixing software with FEniCS is a tutorial on how to combine FEniCS applications in Python with software written in other languages.

Demos

A simple way to build your first FEniCS application is to copy and modify one of the existing demos:

- Documented DOLFIN demos (Python)
- Documented DOLFIN demos (C++)

The demos are *already installed on your system* or can be found in the demo directory of the DOLFIN source tree.

Quick Programmer's References

Some of the classes and functions in DOLFIN are more frequently used than others. To learn more about these, take a look at the

- Basic classes and functions in DOLFIN (Python)
- Basic classes and functions in DOLFIN (C++)

Complete Programmer's References

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http://fenicsproject.org/documentation/

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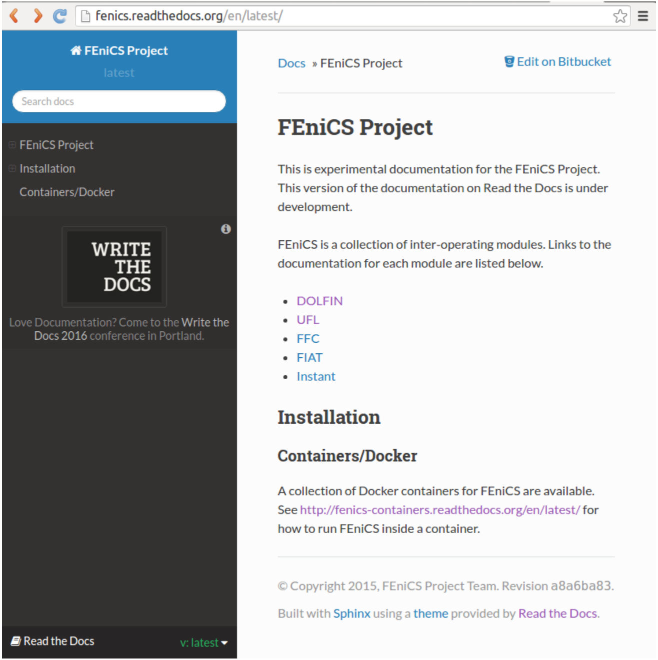
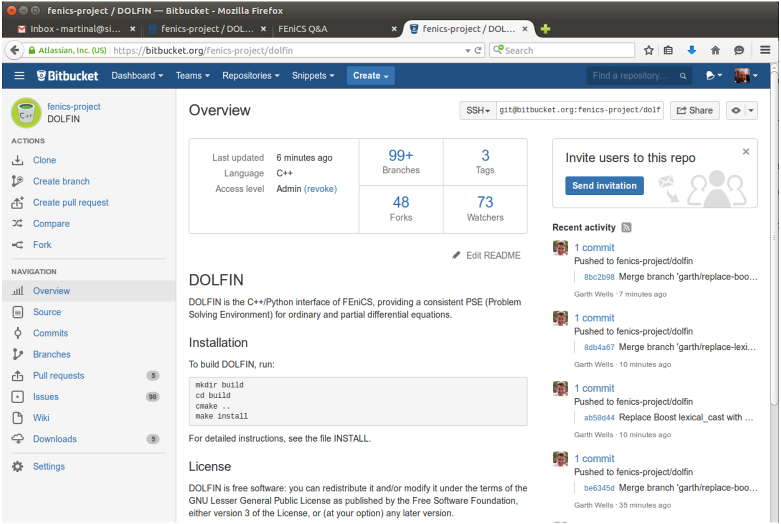


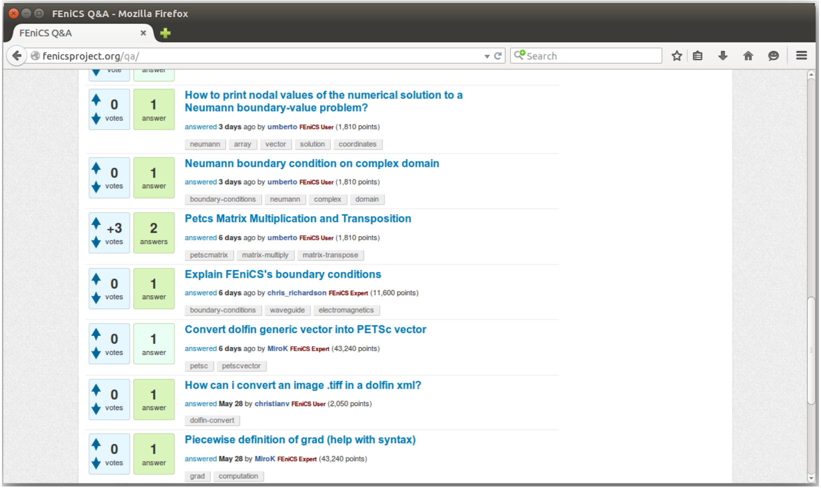
http://fenics.readthedocs.org/

Development community is organized via bitbucket.org



http://bitbucket.org/fenics-project/

Community help is available via QA forum



https://fenicsproject.org/qa

Installation alternatives

- ☞ Docker images on Linux, Mac, Windows
- ☞ Build from source with Hashdist (fenics-install.sh)
- ☞ PPA with apt packages for Debian and Ubuntu
- ☞ Drag and drop installation on Mac OS X

http://fenicsproject.org/download/

Installation using Docker

Follow instructions to install Docker on linux, mac, or windows:

https://docs.docker.com/linux/ or mac/, windows/

Download and open a terminal in a clean FEniCS environment:

Bash code

```bash
$ docker run -ti quay.io/fenicsproject/dev
```

More instructions on using FEniCS Docker images here:

http://fenics-containers.readthedocs.org

Installation using Docker+fenicsproject script

Install Docker, then get the fenicsproject script:

Bash code

```
$ curl -s http://get.fenicsproject.org | sh
```

Now you can initialize and run in a clean FEniCS environment simply with:

Bash code

```
$ fenicsproject create myfenics dev
$ fenicsproject start myfenics
```

Or start a Jupyter notebook in a clean environment with:

Bash code

```
$ fenicsproject notebook mynotebook dev-py3
$ fenicsproject start mynotebook
```

In this course we'll be running on a local Jupyter Notebook server

- Open `nike.simula.no` in a webbrowser
- Click "New", "Python 3"
- Try entering some code:

Python code

```
from fenics import *

%matplotlib inline
parameters["plotting_backend"] = "matplotlib"

mesh = UnitCubeMesh(16, 16, 16)
plot(mesh)
```

Let's get started and remember:

- **Lectures** can be downloaded from

  `http://fenicsproject.org/pub/course/lectures`

- **Data** for exercises can be downloaded from

  `http://fenicsproject.org/pub/course/data`

- **Solutions** for exercises can be downloaded from

  `http://fenicsproject.org/pub/course/src`

  (Secret password needed!)