

FEniCS Course

Overview

Lecturer

Simon Funke

Zhejiang University

Mar 10–14 2014



FENICS
PROJECT

Course outline

Mon **L01** Introduction to FEniCS

L02 Static linear PDEs

Tue **L03** Static nonlinear PDEs

L04 Time-dependent PDEs

L05 Happy hacking: Tools, tips and coding practices

Wed **L06** Computing sensitivities

L07 Introduction to dolfin-adjoint

L08 Incompressible Navier–Stokes

Thu **L09** From sensitivities to optimisation

L10 Optimisation algorithms

L11 Optimal control of the Navier-Stokes equations

Fri **L12** Topology optimisation

L13 One-shot optimisation

Lectures can be downloaded from

<http://fenicsproject.org/pub/course/>



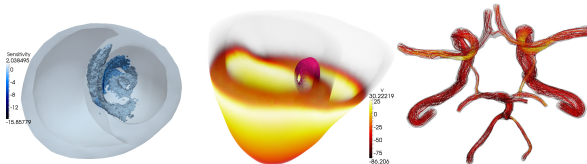
The FEniCS Project is a collection of open-source software components aimed at the numerical solution of partial differential equations using finite element methods

Key distinguishing features

- 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 used to create efficient, low-level code
- Performance – implicit problems with millions DOFs can be solved in minutes
- Automatic adjoint derivation for sensitivity computation and PDE-constrained optimisation

FEniCS can be, and 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 cardiac 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, ...

Sounds great, but how do I find my way through the jungle?



Three survival advices



Use the right Python
tools



Explore the
documentation



Ask, report and
request

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

[All classes and functions in DOLFIN \(Python\)](#)

[All classes and functions in DOLFIN \(C++\)](#)

[All classes and functions in UFL](#)

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

All classes and functions in DOLFIN (Python)

All classes and functions in DOLFIN (C++)

All classes and functions in UFL

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

[All classes and functions in DOLFIN \(Python\)](#)

[All classes and functions in DOLFIN \(C++\)](#)

[All classes and functions in UFL](#)

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

All classes and functions in DOLFIN (Python)

All classes and functions in DOLFIN (C++)

All classes and functions in UFL

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

[All classes and functions in DOLFIN \(Python\)](#)

[All classes and functions in DOLFIN \(C++\)](#)

[All classes and functions in UFL](#)

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 \(C++\)](#)

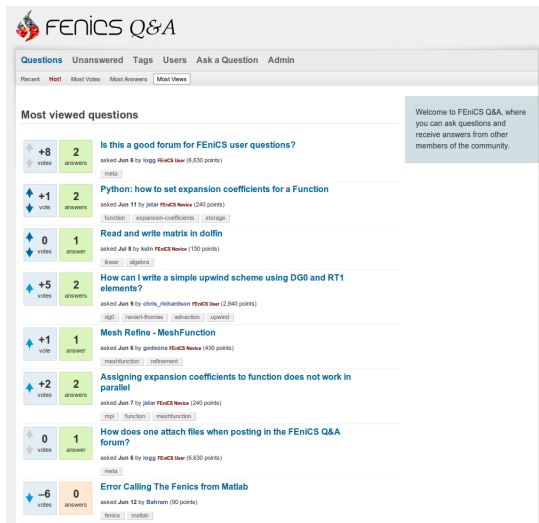
Complete Programmer's References

[All classes and functions in DOLFIN \(Python\)](#)

[All classes and functions in DOLFIN \(C++\)](#)

[All classes and functions in UFL](#)

Getting help from the FEniCS community



The screenshot displays the FEniCS Q&A forum interface. At the top, there is a navigation bar with links for Questions, Unanswered, Tags, Users, Ask a Question, and Admin. Below this, a secondary bar shows filters for Recent, Hot!, Most Votes, Most Answers, and Most Views. The main content area is titled 'Most viewed questions' and lists several questions with their respective vote counts, answer counts, titles, and tags. A welcome message is displayed on the right side of the page.

FEniCS Q&A

Questions Unanswered Tags Users Ask a Question Admin

Recent **Hot!** Most Votes Most Answers Most Views


Welcome to FEniCS Q&A, where you can ask questions and receive answers from other members of the community.

Most viewed questions

- +8 votes** **2 answers** **Is this a good forum for FEniCS user questions?**
asked Jun 6 by **logg** **FEniCS User** (6,630 points)
meta
- +1 vote** **2 answers** **Python: how to set expansion coefficients for a Function**
asked Jun 11 by **Jeter** **FEniCS Newbie** (240 points)
function expansion-coefficients storage
- 0 votes** **1 answer** **Read and write matrix in dolfin**
asked Jul 8 by **Kalle** **FEniCS Newbie** (150 points)
linear algebra
- +5 votes** **2 answers** **How can I write a simple upwind scheme using DG0 and RT1 elements?**
asked Jun 9 by **chris_richardson** **FEniCS User** (2,840 points)
dgp rickard-thomas advection upwind
- +1 vote** **1 answer** **Mesh Refine - MeshFunction**
asked Jun 6 by **gedeon** **FEniCS Newbie** (430 points)
meshfunction refinement
- +2 votes** **2 answers** **Assigning expansion coefficients to function does not work in parallel**
asked Jun 7 by **Jeter** **FEniCS Newbie** (240 points)
mpi function meshfunction
- 0 votes** **1 answer** **How does one attach files when posting in the FEniCS Q&A forum?**
asked Jun 6 by **logg** **FEniCS User** (6,630 points)
meta
- 6 votes** **0 answers** **Error Calling The Fenics from Matlab**
asked Jun 12 by **Bahram** (90 points)
fenics matlab

<http://fenicsproject.org/qa/>

Getting help from the FEniCS community

 FENICS Q&A

Questions Unanswered Tags Users Ask a Question Admin

combining function spaces

★


Welcome to FEniCS Q&A, where you can ask questions and receive answers from other members of the community.

+3
votes

I'd like to create a `FunctionSpace` that is composed of P_2 (with degrees of freedom associated with the nodes and edge midpoints) and B (bubble elements, degrees of freedom associated with the cell center of gravity).

Is this currently possible in FEniCS?


function-space

 asked Jul 25 by [machlow](#) FEniCS User (1,330 points)

[edit](#) [flag](#) [close](#) [hide](#) [Answer](#) [comment](#)

1 Answer

+2
votes

 Best answer

Yes, it is possible:

```
P2 = VectorFunctionSpace(mesh, "Lagrange", 2)
B  = VectorFunctionSpace(mesh, "Bubble", 3)
V = P1 + B
```

Take look at the demo in `dolfin/demo/undocumented/stokes-mini`.

[answered Jul 25](#) by [Garth N. Wells](#) FEniCS User (7,280 points)
[selected Jul 25](#) by [Jan Blechta](#)

[edit](#) [flag](#) [hide](#) [ask related question](#) [comment](#)

<http://fenicsproject.org/qa/>

Community resources

- The FEniCS mailing list
`fenics@fenicsproject.org`
- The FEniCS QA forum
`http://fenicsproject.org/qa/`
- The FEniCS Google+ community
`http://plus.google.com/`
- Twitter
`#fenicsproject`
- The FEniCS developer site (Bitbucket)
`https://bitbucket.org/fenics-project/`

<http://fenicsproject.org/>

Installation



Official packages for Debian and Ubuntu



Drag and drop installation on Mac OS X



Binary installer for Windows



Automated installation from source

<http://fenicsproject.org/download/>

Let's get started!