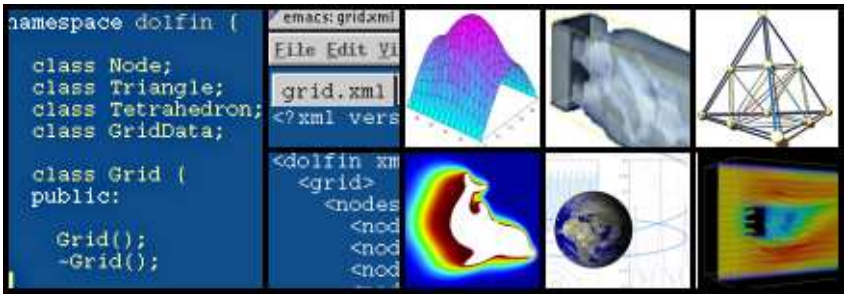
Project Course in Scientific Computing 08

Suggestions for projects



Johan Jansson
Computer Science and Communication
KTH

General guidelines

This document contains a list of suggested projects. Since these are only suggestions, you are welcome with your own ideas. Regard the list as an inspiration, and perhaps a hint on the expected level of your projects.

Concerning grades, the projects are divided into two parts: basic level and advanced level. Basic level means maximum grade C and advanced level means maximum grade A. It is also required that your report match the level of your project.

Good luck!
Johan

1 Implementing heart attacks in the Human Heart model

In one of the CTL (`http://ctl.csc.kth.se/`) projects the analysis, development and implementation of the movement of the heart based on the Finite Element Method is aimed. The modeling is based on the Navier Stokes equation for incompressible flow using the stabilized Galerkin method.

`http://ctl.csc.kth.se/index.php/Finite_Element_Modeling_of_the_Human_Heart`

The goal of the proposed project is to simulate heart attacks triggered in different segments in the heart wall. The main steps in this project is to get familiar with FEniCS (`http://www.fenics.org/wiki/FEniCS_Project`), the software used for the implementation, and to modify the existing code for the simulation:

(`http://www.nada.kth.se/utbildning/grukth/exjobb/rapportlistor/2009/` - see Matthias Aechtner).

Advanced

Nothing extra is needed for advanced level.

2 Flight simulation

Investigate using Unicorn/FEniCS finite element technology/solver for turbulent flow how flying works:

http://knol.google.com/k/claes-johnson/why-it-is-possible-to-fly/yvfu3xg7d7wt/18#

http://www.csc.kth.se/~jhoffman/pub/v4.pdf

The project can consider technical parts of the simulation, supporting master thesis/phd student projects on similar topics. An example could be aspects of defining geometry/mesh and setting up simulation parameters in a systematic way.

Advanced

Compute a full simulation of a flying wing and try to explain the mechanism of flying.

3 Chemical reactions

Simulate the following system of chemical reactions, where the substances A and B react to form C: $A + B \to C$.

Consider a beaker containing a solution of A with given concentration. To this beaker, we add a drop of B every second until finally A has "completely" reacted with B. Try to find a suitable reaction to simulate in a chemistry book. Maybe the reaction you want to simulate is instead given by $2A + 3B \to 4C$, or perhaps $5A + 2B + C \to 2C$?

Model this as a system of reaction–diffusion equations, where $u_1(x, t)$ and $u_2(x, t)$ are the two concentrations to be determined.

Implement your 2D/3D solver in FEniCS/DOLFIN.

Advanced

Consider error control and adaptivity.

References

1. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
2. *Computational Differential Equations*, by Eriksson, Estep, Hansbo, and Johnson. Studentlitteratur 1996.
3. Some suitable book on chemistry.

4 Heat equation

Implement a solver for the heat equation in 2D/3D and apply the solver to a realistic problem. Compute error estimates (energy norm and/or some quantity of the solution). Compare your results to known data or a model problem with exact solution and study convergence with regard to mesh size h and time step k.

Advanced

Implement space-time adaptivity.

References

1. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
2. *Computational Differential Equations*, by Eriksson, Estep, Hansbo, and Johnson. Studentlitteratur 1996.

5 The Navier-Stokes equations

Implement a solver for the Navier-Stokes equations in 2D or 3D.

Advanced

Nothing extra is needed for advanced level.

References

1. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
2. *Computational Differential Equations* by Eriksson, Estep, Hansbo, and Johnson. Studentlitteratur 1996.
3. *Computational Turbulent Incompressible Flow* by Hoffman and Johnson. Springer, 2007 `http://www.springer.com/math/cse/book/978-3-540-46531-7`.

6 Elasticity

Implement a solver for linear elasticity in 2D/3D and consider adaptivity.

Advanced

Consider large displacements/deformations or a multiphysics application (fluid-structure interaction, elasticity-electromagnetics, etc.)

References

1. *Beyond the Elements of Finite Elements: General Principles for Solid and Fluid Mechanics Applications* by Hansbo. Department of Solid Mechanics, Chalmers University of Technology, 2002

7 The Wave equation

Read the technical report by L.Beilina and implement the hybrid method in 2D.

Advanced

Implement the absorbing boundary condition.

References

1. *A Hybrid Method for the Wave Equation*, by L. Beilina, Technical report, Chalmers Finite Element Center (2001)
2. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
3. *Computational Differential Equations* by Eriksson, Estep, Hansbo and Johnson. Studentlitteratur 1996.

8 Bistable equation

Write a solver in Dolfin for the bistable equation in 2D/3D, which is an easy example of a nonlinear PDE, consider fixed-point iteration and Newton's method.

Advanced

Consider error estimation and adaptivity using duality.

References

1. *Body and Soul computer sessions (Reaction-Diffusion)*: `http://www.phi.chalmers.se/bodysoul/sessions/`.

9 The compressible Euler equations

Implement a solver for the compressible Euler equations in FEniCS (very advanced) with a simple model problem. Contact me for further details.

Advanced

Nothing extra is needed for advanced level.

References

1. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
2. *Computational Differential Equations* by Eriksson, Estep, Hansbo, and Johnson. Studentlitteratur 1996.

10 Maxwell's equations

Implement a solver for Maxwell's equations in FEniCS (fairly advanced). You can choose to use edge elements (Nedelec) or a stabilized method achieve this. Ask the teacher for material on computational electromagnetics if you are interested in such a project.

Advanced

Nothing extra is needed for advanced level.

References

1. *Applied Mathematics: Body and Soul*, by Eriksson, Estep, and Johnson, Springer Verlag 2003.
2. *Computational Electromagnetics* by Bondeson, Rylander and Ingelstrm. Springer 2005.