Computational methods for fluid mechanics

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Abstract

The summer school consists of four days focused on computational methods for fluid mechanics. After a brief overview of different computational methods, we will focus on variational methods (finite element methods) for incompressible flow, which fit well with the dominant mathematical theory of the Navier-Stokes equations. Lectures will be mixed with laboratory work using a web-based interactive computational platform based on the open-source software platforms FEniCS and Jupyter.

https://fenicsproject.org
https://jupyter.org

Day 1: Viscous incompressible flow

Introduction to conservation laws and incompressible flow, Navier-Stokes equations, and different computational methods used in science and industry. Mathematical theory and finite element methods for viscous flow (Stokes equations).

Day 2: The Navier-Stokes equations

The Navier-Stokes equations as a dynamical system, stability analysis, and the structure of turbulent flow. Semi-discretization by a finite element method and time stepping, residual-based stabilization, and simulation of turbulence.

Day 3: Error estimation and adaptive methods

Existence and uniqueness of the Navier-Stokes equations, weak solutions, and a $1 million Clay Prize problem. Adaptive finite element methods and a posteriori error analysis, dissipative weak solutions, and the Onsager conjecture.

Day 4: Fluid-structure interaction

Boundary layers, flow separation, and wall modelling. The structure of turbulent flow separation, analytical models, and the d'Alembert's paradox. Deforming domains and fluid-structure interaction, mesh and meshless computational methods, finite element methods.