IS 07 An Invitation to Computational Fluid Dynamics: From Fundamentals to Applications

Course Content and Schedule

The course will consist of five theoretical and practical sessions, held in the simulation classroom of the School of Engineering. Each session will last four hours. The first hour will cover theoretical fundamentals, followed by three hours of practical exercises on computers under the supervision of professors.

Program:

Day 1:

- Introduction to the Numpy environment, Matplotlib
- Solution of ordinary differential equations using the explicit Euler method
- Stability of solutions: The implicit Euler method
- Accuracy of the solution: Second-order methods
- Solution of systems of ordinary differential equations
- Calculation of numerical errors
- The Lorenz system as a paradigm of chaotic systems
- Properties of chaotic systems: Stability and Lyapunov exponents
- Measurement of error in a chaotic system: Sampling errors

Day 2:

- Types of partial differential equations
- The non-stationary heat equation as a paradigm of parabolic equations
- Discretization in space and time: Difference between boundary and initial conditions
- Errors due to discretization in space and time
- Implicit solution in time of the heat equation

Day 3:

- Poisson's equation as a paradigm of elliptic equations
- Direct solution of an elliptic equation and its challenges
- Iterative methods for solving elliptic equations
- Concept of residual: Difference between error and residual

Day 4:

- The advection equation as a paradigm of hyperbolic equations
- Solution methods and stability considerations
- Differences between diffusive and dispersive errors
- The Burgers equation and the acoustics equation as extensions of the advection equation
- Application to the Navier-Stokes equations

Day 5:

- OpenFOAM as an example of full-featured CFD software
- Description of components with comparison to previously covered concepts
- Examples of OpenFOAM use in industrial and academic cases

Course Objectives

At the end of this course, students will have acquired the following capabilities:

1. Distinguish between hyperbolic, elliptic, and parabolic equations.
2. Understand the different types of strategies used to solve each of these problems and be able to program these strategies for simple problems.
3. Categorize the equations of Fluid Mechanics into parabolic, hyperbolic, and elliptic parts.
4. Understand how different solving strategies are employed simultaneously in most problems and observe this in open-source industrial software.
5. Apply this knowledge to understand the operation of commercial programs where source code is not available.