LUNDS UNIVERSITET
Lunds Tekniska Högskola

Course syllabus

Numeriska simuleringar av flödesproblem
Numerical Simulations of Flow Problems

FMNN40, 7,5 credits, A (Second Cycle)

Valid for: 2023/24
Faculty: Faculty of Engineering, LTH
Decided by: PLED F/Pi
Date of Decision: 2023-04-18

General Information

Elective for: F4, F4-bs, Pi4-bs
Language of instruction: The course will be given in English

Aim

The overall goal of the course is that the student should acquire basic knowledge in modern numerical methods for non-linear conservation laws, with a focus on fluid models.

Important examples of such models are the Euler equations of gas dynamicsand the shallow water equations, both of which are simplifications of the Navier-Stokes equations. These
models are used in the design of aircraft and wind turbines, as well as in climate system research.

The course discusses so called finite volume methods for discretizing the models, their derivation, convergence and stability properties, and touches upon higher order extensions.

The discretization often leads to large nonlinear systems of equations. The course presents iterative methods for solving these, such as Multigrid and Newton-Krylov. Their convergence properties are discussed, with a particular focus on systems arising from the above discretizations.

Learning outcomes

Knowledge and understanding

For a passing grade the student must

- be able to give an account of mathematical and numerical difficulties arising with nonlinear conservation laws and shock solutions,
- be able to explain stability and convergence of discontinuous Galerkin methods,
- be able to describe the structure of Jacobian-free Newton-Krylov methods,
- be able to describe multi-grid methods and their use for flow problems.

Competences and skills
For a passing grade the student must

- be able to derive a discontinuous Galerkin method for a general conservation law,
- be able to implement a discontinuous Galerkin method for a one dimensional nonlinear conservation law,
- be able to interpret numerical stability and accuracy problems arising in simulations,
- be able to implement a Jacobian-free Newton-Krylov method with preconditioner,
- be able to implement a multigrid method and apply it to flow problems,
- be able to integrate knowledge from the various parts of the course to address problems within the framework of the course,
- be able to plan and execute qualified tasks within the framework of the course, with appropriate methods within given time-frames.

Judgement and approach
For a passing grade the student must

- be able to critically evaluate and independently apply methods from the course within a project work,
- be able to evaluate their own responsibility for how the subject is used and discuss the subject's possibilities to contribute to a sustainable social development.

Contents

- Models of computational fluid dynamics
- Hyperbolic conservation laws and their basic properties (weak solutions, weak entropy solutions, shocks)
- Discontinuous Galerkin discretizations
- Simulations of gas dynamics
- Krylov subspace methods with preconditioning
- Jacobian-free Newton-Krylov methods
- Multigrid methods for flow problems

Examination details

Grading scale: TH - (U,3,4,5) - (Fail, Three, Four, Five)
Assessment: The examination consists of a written report of the final project and an appurtenant oral examination based on the report. The oral examination is only given to those students who have passed the written report. Students who fail the regular examination are offered a re-examination shortly thereafter.

The examiner, in consultation with Disability Support Services, may deviate from the regular form of examination in order to provide a permanently disabled student with a form of examination equivalent to that of a student without a disability.

Parts

Code: 0123. **Name:** Project Report.
Credits: 3,5. **Grading scale:** UG. **Assessment:** Written report on the final project.
Code: 0223. **Name:** Examination.
Credits: 4. **Grading scale:** TH. **Assessment:** Oral examination on the written project report.

Admission

Admission requirements:

- FMNN10 Numerical Methods for Differential Equations

Assumed prior knowledge: FMAB35 Calculus in Several Variables, and FMAN55 Applied Mathematics.
The number of participants is limited to: No
The course overlaps following course/s: NUMN28

Reading list

- Philipp Birken: Numerical Methods for Unsteady Compressible Flow Problems. CRC Press, 2021, ISBN: 9780367457754. Also as e-book.
- Randall J. LeVeque: Numerical Methods for Conservation Laws. Birkhäuser Verlag AG, 2008, ISBN: 9783764327231. Softcover reprint of second edition from 1992.

Contact and other information

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Course homepage: https://canvas.education.lu.se/courses/22833