Advanced Computation in Fluid Mechanics
Course PM 2010

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Description

Advanced trans-disciplinary course approaching fundamental problems in fluid mechanics of major practical importance by tools from mathematical analysis and numerical analysis, using modern computational technology.

Prerequisites

The course DN2260 Finite element methods, or equivalent.

Aim

The goal is that the students should be able to analyze and use General Galerkin (G2) adaptive finite element computational technology to model fluid flow at high Reynolds numbers. More precisely, the students should be able to:

- define the concepts weak solution and well-posedness,
- derive energy estimates for underlying equations and G2 approximations,
- derive a posteriori output error estimates for G2 using duality,
- analyze the global effect of friction boundary conditions in G2,
- use G2 software for adaptive flow computations with error control.

Based on a critical review of research literature and the students own G2 computations, the student should be able to analyze the following fundamental (open) problems of state of the art fluid mechanics using G2 computation/analysis:

- turbulence and well-posedness of the basic mathematical models,
- boundary conditions, turbulent boundary layers and flow separation,
- accurate computational prediction of aerodynamic forces,

with applications in a number of areas such as car-, ship- and aircraft industry. The purpose is to develop a critical approach with the possibility to question established truths, and to form new hypotheses.

Examination

Below is listed the course examination together with respective deadlines:

Exam (4.0 hp)

- Problem sheet 1-10: Monday 8.00 February 8 (50%)
- Oral exam (Problems 1-10): Monday February 8 (pass/fail)
- Project report (10 pages/group: pdf-file): Monday 8.00 March 8 (50%)
- Oral presentation of final report: Wednesday 10.15 March 10 (pass/fail)

Project (3.5 hp)

- Computer Lab report (5 pages: pdf-fil): Monday 8.00 February 15 (pass/fail)
- Peer review report (1 page: pdf-file): Wednesday 8.00 March 10 (pass/fail)
- Opponent final presentations: Wednesday 10.15 March 10 (pass/fail)

Each part of the examination is mandatory to pass the course, and attendance to the seminars is also mandatory. All submissions should be sent by email to the course leader and the teaching assistant in time for the deadlines, and the only accepted format is pdf-files. Except for the problem sheet: here also paper submissions to the teaching assistant are accepted. The problem sheet, the computer lab report, and the peer review report is submitted individually, whereas the project reports are submitted one for each group.

The percentages refer to the respective weights the activities have for the total grade. The quality of each activity is then also graded, so that the total grade is given as the sum of the percentages times the quality (0-100%) of each activity. The total grade for the Exam and Project is given according to the following scale:

A 90%

B 80%

C 70%

D 60%

E 50%

F <50%

Failure to comply with deadlines for submissions automatically reduces the quality of the activity.

Course plan

Seminar 1

- Thermodynamics, incompressible flow, stability, vorticity
- Problem sheet: 1-4
- Reading: [1] (chapters 1-12)

Seminar 2

- General Galerkin (G2) method, skin friction boundary conditions
- Problem sheet: 5-7
- Reading: [1] (chapters 16, 25-29)

Seminar 3

- Linearized dual problem, a posteriori error estimation, adaptive method
- Problem sheet: 8-10
- Reading: [1] (chapters 30,33)

Seminar 4

- The d'Alembert paradox, boundary conditions, flow separation

Seminar 5

- Turbulence, blowup, Clay $1 million Prize

Seminar 6

- Aerodynamics, drag and lift generation, flying

Seminar 7

- Presentations of final report

References

[1] J. Hoffman and C. Johnson, *Computational Turbulent Incompressible Flow: Applied Mathematics Body and Soul Vol 4*, Springer-Verlag Publishing, 2006.

Contact

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