CIVIL-471

Computational hydrodynamics

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Cursus	Sem.	Type
Civil Engineering	MA1, MA3	Opt.
Civil engineering minor	H	Opt.

Language of teaching	English
Credits	5
Session	Winter
Semester	Fall
Exam	Oral
Workload	150h
Weeks	14
Hours	**4 weekly**
Lecture	2 weekly
Exercises	2 weekly
Number of positions	

Remark

Uniquement donné en 2024-25

Summary

Computational Hydrodynamics is an advanced course designed to explore the fundamental principles, methods, and applications of numerical techniques to hydrodynamics. Through this course students will be able to solve the fluidic governing equations, where no analytical solution is available.

Content

This course will introduce students to computational modelling, focusing on advection-diffusion dominated problems. Upon introduction and classification of problems, several techniques for spatial and temporal discretization will be covered. The course, then covers pre-mid-post processing methods, used to increase the efficiency, accuracy and processing resources. The course will be offered through the following 3 main modules:

Module 1: Fluid dynamics and modelling This module includes derivation and discussion on mathematical models, including linear and non-linear terms. The nature of the mathematical models with be discussed and common approximations, limitations, and simplifications commonly applied will be described and analyzed. Time and space progression in a hydrodynamic model depends on the initial and boundary values. In this module types of boundary conditions, such as periodic and Neumann's boundary conditions, will be discussed.
Module 2 Numerical methods and solution Different spatial discretization techniques will be explored, compared, and analyzed. Time-dependent methods will also be explored (implicit vs explicit) with more emphasis on explicit and semi-explicit time advancement methods that are commonly used in practice. Topics related to tempo-spatial discretization including numerical stability, convergence, and grid quality will be discussed.

Module 3: Analysis, assessment, and additional topics: Efficiency and accuracy are the key aspects of computational modelling. The scientific challenge is to develop numerical methods or algorithms that provide an accurate solution in a more efficient manner. Methods will be introduced to evaluate and compare the accuracy and efficiency of various spatial and temporal schemes. Also, alternative streams of data processing beyond postprocessing, such as in-transit processing will be explored and tested. Additionally, in the last two lectures an introduction to turbulence modeling will be made. Specifically, Reynolds-averaged Navier-Stokes equations and Reynolds stress and the turbulence closure problem will be discussed and implemented. Additional turbulent modelling approaches including large-eddy simulation and direct numerical simulations will be introduced.

Keywords

Computational methods, Hydrodynamics, Time discretization, convergence, method of characteristics, method order

Learning Prerequisites

Required courses

Partial Differential Equations, Fluid Mechanics

Important concepts to start the course

Mass and momentun conservation, familiar with partial differential equations, basic computational methods

Learning Outcomes

By the end of the course, the student must be able to:

- Formulate fluid concepts. The student will demonstrate an ability to formulate the type of fluid flow that is occurring in a particular physical system and to use the appropriate model equations to investigate the flows.
- Characterize open channel hydrodynamics. Students will be able to characterize basic principles of open channel hydrodynamics.
- Create numerical algorythms. Students will be able to create and develop advanced numerical algorithms to form efficient and convergent solutions to hydrodynamic challenges.
- Implement Through the completion of this course and related assignments and tasks, students will implement advanced algorithms to solve Fluidic Problems.

Transversal skills

- Use a work methodology appropriate to the task.
- Set objectives and design an action plan to reach those objectives.
- Communicate effectively, being understood, including across different languages and cultures.
- Plan and carry out activities in a way which makes optimal use of available time and other resources.

Teaching methods

Powerpoint, Discussion, Notes, in-class exercice

Expected student activities

Attending lectures ; Attending weekly excercise ; home study, completing assessments

Assessment methods

Assignments (50%),
Deliverables are Python codes and full reports (weekly/biweekly) ;
Challenges (10%) ;
Final project (40%) includes interim and final presentations

Supervision

Office hours	Yes
Assistants	Yes
Forum	Yes

Resources

Virtual desktop infrastructure (VDI)

Yes

Bibliography

Course notes provided to students.Popescu, I. (2014). Computational hydraulics. IWA Publishing;Magoulès, F. (2011). Computational fluid dynamics. CRC Press

Ressources en bibliothèque

- Computational fluid dynamics / Magoules
- Computational hydraulics / Popescu