ME-476

Particle-based methods

Gaume Johan, Li Xingyue

Cursus	Sem.	Type
Computational science and Engineering	MA1, MA3	Opt.
Mechanical engineering minor	H	Opt.
Mechanical engineering	MA1, MA3	Opt.

Language of teaching	English
Credits	4
Withdrawal	Unauthorized
Session	Winter
Semester	Fall
Exam	During the semester
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	1 weekly
Exercises	1 weekly
TP	2 weekly
Number of positions	

It is not allowed to withdraw from this subject after the registration deadline.

Summary

This course provides an introduction to particle-based methods for the numerical resolution of partial differential equations describing continuum phenomena or for the simulation of particulate flows. Details are given for the Material Point Method (MPM) and the Discrete Element Method (DEM).

Content

Particle-based computational methods are being increasingly employed for solving a variety of problems in engineering and applied science. While such methods can yield significant advantages compared to traditional mesh-based methods, their accurate and efficient implementation also provides a number of challenges.
This course presents the fundamental aspects of two methods:

- *Material Point Method (MPM)* is a hybrid Eulerian-Lagrangian numerical scheme for solving continuum mechanics problems. It is particularly well suited to simulate problems involving large deformations, collisions, fractures and the interaction between different materials (solids, fluids and gases). Material points are used to track the motion and carry information while a background mesh is used to compute spatial gradients.
- *Discrete Element Method (DEM)* is used for simulating granular and particulate flows and tracks particle motions and detects and models collisions between particles and with their environment. It relies on the equations of Newton and a variety of contact models.

The course provides an introduction to these two methods and their domains of application (e.g. fluid and solid mechanics, computer graphics). The theoretical basis of each method is presented in introductory lectures. Following a literature search, students give oral presentations on a specific article about DEM or MPM and explain more advanced aspects. Mini-project using open-source softwares provide practical experience in the application of these methods. Illustrations of the use of particle-based methods is also provided by researchers from industry and other universities.

Keywords

Numerical simulation, Fluid and granular flow, Slope stability, Material Point Method, Discrete element method

Learning Prerequisites

Required courses

- Numerical analysis
- Discretization methods (e.g. finite differences, finite elements, finite volumes)
- Advanced fluid and solid mechanics
- Continuum mechanics

Important concepts to start the course

- Numerical simulation in fluid or solid mechanics

Learning Outcomes

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

- Describe the difference between the Eulerian and Lagrangian approaches
- Identify and apply the different steps in a numerical simulation (e.g. geometry and mesh generation, computation, post-processing) and integrate all the essential basic concepts in a numerical flow simulation
- Describe different methods used to discretize differential equations, such as finite differences, finite elements, MPM, SPH, PFEM
- Perform a numerical simulation with appropriate software; understand the limits of each software in terms of its application domain and accuracy of the results obtained

Transversal skills

- Give feedback (critique) in an appropriate fashion.
- Use both general and domain specific IT resources and tools
- Summarize an article or a technical report.
- Make an oral presentation.
- Write a scientific or technical report.
- Assess one's own level of skill acquisition, and plan their on-going learning goals.

Teaching methods

Lectures, literature review, analysis of scientific articles, group talks, practical numerical simulations, individual mini-project

Expected student activities

- Interactivity in the classroom
- Literature search and private study
- Oral presentations in groups and individually
- Mini-project (written report and oral presentation)

Assessment methods

Continuous evaluation by group talks, article oral presentation and mini-project written report & oral presentation.

Supervision

Office hours	No
Assistants	Yes
Forum	No

Resources

Bibliography

Course material is available on-line; various reference texts

Moodle Link

- http://moodle.epfl.ch/course/view.php?id=10431