CIVIL-408

Multiscale modelling in mechanics

Karapiperis Konstantinos

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

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

Summary

This course introduces the principles and techniques for modeling materials across different spatial scales, from the level of atoms or grains to the continuum or structural scale. Emphasis is placed on hierarchical upscaling (homogenization), while concurrent techniques are also covered.

Content

- Introduction to multiscale modeling
- Periodic and random microstructures, representative volume element
- Review of continuum mechanics and the finite element method
- Atomistic, discrete element and mesoscale methods
- Continuum-to-continuum computational homogenization, Hill-Mandel condition
- Asymptotic homogenization, Estimates and bounds for effective moduli
- Discrete-to-continuum homogenization
- Analytical methods, Cauchy-Born rule
- Concurrent multiscale modeling
- Data-driven multiscale modeling
- Applications to different classes of materials (composites, granular materials, concrete, masonry, metals, architected materials, ...)

Keywords

Multiscale modeling, solid mechanics, homogenization, molecular dynamics, discrete element method

Learning Prerequisites

Required courses

Continuum Mechanics (e.g. CIVIL-225), Finite Elements (e.g. CIVIL-321), Numerical analysis (e.g. MATH-251a)

Important concepts to start the course

Mechanics of deformable media,
Linear algebra, Tensor analysis, Numerical analysis

Learning Outcomes

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

- Assess / Evaluate mechanical modeling techniques at different scales.
- Apply theoretical and computational approaches for bridging scales in solid mechanics.
- Develop and implement scale-bridging algorithms in Python.

Transversal skills

- Set objectives and design an action plan to reach those objectives.
- Demonstrate the capacity for critical thinking
- Use both general and domain specific IT resources and tools
- Make an oral presentation.

Teaching methods

2 hours lectures, 2 hours in exercise or computer room.

Expected student activities

Active participation, home study, programming assignments and exercises.

Assessment methods

Individual computational project in Python (80%), presentation of a research paper (20%).

Supervision

Office hours	Yes
Assistant.e.s	Yes
Forum	Yes

Resources

Virtual desktop infrastructure (VDI)

No

Bibliography

- Lecture notes and articles given during the lecture
- Modeling Materials by E. Tadmor
- Multiscale Modeling by D. Kochmann

Ressources en bibliothèque

- Find the references at the Library
- Multiscale Modeling / Kochmann

Moodle Link

- https://go.epfl.ch/CIVIL-408