IMT SCHOOL FOR ADVANCED STUDIES LUCCA

PhD in Systems Science, A.Y. 2020-2021

Syllabi

Computational Mechanics Courses

Marco Paggi
17/11/2020

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Numerical Methods for the Solution of Partial Differential Equations
Lecturer: Marco Paggi
Hours: 20

Syllabus

Learning Outcomes:

Ability to solve numerically a problem related to a physical system and predict its response. The physical system can be embedded within an optimization problem, for instance, or it can be part of a complex system (biological, mechanical, thermo-mechanical, chemical, or even financial) you are interested in predicting its behaviour and evolution over time.

Abstract:

The course introduces numerical methods for the approximate solution of initial and boundary value problems governed by linear and nonlinear partial differential equations (PDEs) used to describe physical systems. The fundamentals of the finite difference method and of the finite element method are introduced step-by-step in reference to exemplary model problems taken from heat conduction, linear elasticity, and pricing of stock options in finance. Notions on numerical differentiation, numerical integration, interpolation, and time integration schemes are provided. Special attention is given to the implementation of the numerical schemes in finite element analysis programmes for fast intensive computations.

Lecture Contents:

- Numerical differentiation schemes
- Numerical interpolation schemes
- Numerical integration schemes
- Time integration algorithms
- Newton-Raphson incremental-iterative schemes for nonlinear problems
- Finite difference method
- Finite element method

Teaching Method:

Blackboard. Due to the Covid-19 emergency, lectures will be provided online:
https://zoom.us/j/93898866026?pwd=aXozRlFBMEFEVEdRb0d1eG9wSm9tZz09

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Bibliography:

- A. Quarteroni, Numerical Models for Differential Problems, Second Ed. Springer, 2013.
- K.-J. Bathe, Finite Element Procedures, Pearson College Div, 2005.
- N. Hilber, O. Reichmann, C. Schwab, C. Winter, Computational Methods for Quantitative Finance, Springer, 2013.

Final Exam:

An application of the taught methodologies to one case study of relevance for the PhD student's research is recommended. Alternatively, a topic to investigate can be suggested by the lecturer.

Prerequisites:

The course is self-contained. Fundamentals of algebra are required.

Schedule Information

Lecture	Day	Time
1	09/12/2020	11.00-13.00
2	10/12/2020	11.00-13.00
3	14/12/2020	9.00-11.00
4	15/12/2020	9.00-11.00
5	17/12/2020	9.00-11.00
6	11/01/2021	9.00-11.00
7	12/01/2021	9.00-11.00
8	13/01/2021	9.00-11.00
9	25/01/2021	9.00-11.00
10	27/01/2021	9.00-11.00

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Funding and Management of Research and Intellectual Property
Lecturer: Marco Paggi
Hours: 10

Syllabus

Learning Outcomes:

How to write a research/mobility project proposal; fundamentals on the management of intellectual property rights.

Abstract:

The long seminar aims at providing an overview of funding opportunities for PhD students' mobility, post-docs, and researchers (Erasmus+ scheme; scholarships by the Alexander von Humboldt Foundation; initiatives by the Deutscher Akademischer Austausch Dienst; scholarships offered by the Royal Society in UK; bilateral Italy-France exchange programmes; Fulbright scholarships; Marie Curie actions; grants for researchers provided by the European Research Council). For each funding scheme, specific hints on how to write a proposal are given. In the second part of the long seminar, fundamentals on the management of intellectual property rights (copyright transfer agreements, open access, patents, etc.) are provided.

Lecture Contents:

- Overview of funding schemes to support research mobility;
- Fundamentals of Intellectual Property Rights (patents, copyrights, etc.);
- Fundamentals of academic entrepreneurship.

Teaching Method:

Powerpoint presentations. Due to the Covid-19 emergency, lectures will be provided online:
https://zoom.us/j/93898866026?pwd=aXozRlFBMEFEVEdRb0d1eG9wSm9tZz09

Bibliography:

Handouts are provided to the participants.

Final Exam:

This long seminar has no final exam.

Prerequisites:
None

Schedule Information

Lecture	Day	Time
1	01/02/2021	9.00-11.00
2	02/02/2021	9.00-11.00
3	08/02/2021	9.00-11.00
4	09/02/2021	9.00-11.00
5	11/02/2021	9.00-11.00

Computer-Aided Engineering for Virtual prototyping and Advanced Manufacturing
Lecturers: Marco Paggi and Andrea Amicarelli
Hours: 10

Syllabus

Learning Outcomes:

Overview of Computer-Aided Engineering (CAE) software for solid and fluid dynamics; CAD-CAE integration software; overview of fast prototyping solutions with examples of high industrial relevance.

Abstract:

This course aims at introducing doctoral students to the state-of-the-art of methods and tools of Computer-Aided Engineering (CAE), which refers to the broad use of computer software to aid in engineering design tasks. It encompasses finite element analysis (FEA), computational fluid dynamics (CFD), analysis tools for industrial process simulation, multi-physics simulation software for smart systems, and also platforms allowing the integration with control and optimization for the product or process. This field is one of the pillars of Industry 4.0, since it allows for virtual testing and virtual and rapid prototyping of materials, components and processes, reducing the time to market of new products and leading to higher levels of performance and reliability.

Lecture Contents:

The course covers the following content:
- Overview of Computer-Aided Engineering software, with special focus on finite element analysis and computational fluid dynamics tools.
- Overview of techniques for CAD-CAE integration, including isogeometric finite elements.
- Overview of 3D prototyping techniques.
- Introduction to CFD Smoothed Particle Hydrodynamics software (SPHERA).
- High-performance computing techniques for the analysis of industrial problems.

Teaching Method:

Powerpoint presentations. Due to the Covid-19 emergency, lectures will be provided online: https://zoom.us/j/93898866026?pwd=aXozRlFBMEFEVEdRb0d1eG9wSm9tZz09

Bibliography:
Handouts are provided to the participants.

Final Exam:
The final exam consists of an application of one of the taught methodologies to a case study of interest for the PhD students' research.

Prerequisites:
It could be useful to attend the course on Numerical Methods for the Solution of Partial Differential Equations. However, the present course is self-contained.

Schedule Information

Lecture	Day	Time
1	15/02/2021	14.00-16.00
2	16/02/2021	14.00-17.00
3	24/02/2021	14.00-16.00
4	25/02/2021	14.00-17.00

Computational Contact and Fracture Mechanics
Lecturer: Marco Paggi
Hours: 20

Syllabus

Learning Outcomes:
The course provides a comprehensive overview of theory and numerics for the understanding and simulation of frontier research topics relevant for the design of innovative materials and structures.

Abstract:
This course provides an overview on the theories of contact and fracture mechanics relevant for a wide range of disciplines ranging from materials science to engineering. Introducing their theoretical foundations, the physical aspects of the resulting nonlinearities induced by such phenomena are emphasized. Numerical methods (FEM, BEM) for their approximate solution are also presented together with a series of applications to real case studies.

Lecture Contents:
The course covers the following topics:
- Hertzian contact between smooth spheres;
- the Cattaneo-Mindlin theory for frictional contact;
- numerical methods for the treatment of the unilateral contact constraints;
- contact between rough surfaces;
- fundamentals of linear elastic fracture mechanics;
- the finite element method for crack propagation;
- nonlinear fracture mechanics and the cohesive zone model;
- interface finite elements;
- applications of fracture mechanics to materials science, retrofitting of civil/architectonic structures, composite materials;
- fatigue.

Teaching Method:
Powerpoint presentations. Due to the Covid-19 emergency, lectures will be provided online:
https://zoom.us/j/93898866026?pwd=aXozRlFBMEFEVEdRb0d1eG9wSm9tZz09

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Bibliography:

M. Paggi, D. Hills (2020) Modeling and Simulation of Tribological Problems in Technology, Springer, https://link.springer.com/book/10.1007/978-3-030-20377-1

Final Exam:

An application of the taught methodologies to a problem of interest for the PhD student's research is recommended. Alternatively, a topic for the exam can be suggested by the lecturer.

Prerequisites:

Numerical Methods for the Solution of Partial Differential Equations.

Schedule Information

Lecture	Day	Time
1	01/03/2021	9.00-11.00
2	02/03/2021	9.00-11.00
3	08/03/2021	9.00-11.00
4	09/03/2021	9.00-11.00
5	15/03/2021	9.00-11.00
6	16/03/2021	9.00-11.00
7	22/03/2021	9.00-11.00
8	23/03/2021	9.00-11.00
9	29/03/2021	9.00-11.00
10	30/03/2021	9.00-11.00

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics of Computational Mechanics
Lecturers: Marco Paggi, Pietro Lenarda
Hours: 20

Syllabus

Learning Outcomes:

Overview of interdisciplinary frontier research topics where computational methods can be profitably applied as predictive simulation tools. Nonlinear coupled problems in solid mechanics and fluid dynamics problems in biomechanics will be the main object of the lectures.

Abstract:

This course covers advanced topics of computational mechanics, with special emphasis on nonlinear coupled problems in solid mechanics and fluid dynamics. This course aims at providing an overview of frontier research topics in emerging interdisciplinary areas where computational methods can be profitably applied as predictive simulation tools.

Lecture Contents:

The course content covers the following topics:
- Advanced techniques for solid mechanics and fluid dynamics;
- Coupled problems in biomechanics;
- Coupled problems for renewable energy applications;
- Computational methods for the prediction of the evolution of discrete mechanical systems and interdisciplinary analogies (traffic networks, economic networks, etc.)

Teaching Method:

Powerpoint presentations. Due to the Covid-19 emergency, lectures will be provided online: https://zoom.us/j/93898866026?pwd=aXozRlFBMEFEVEdRb0d1eG9wSm9tZz09

Bibliography:

Selection of scientific articles published in international journals.

Final Exam:

An application of the taught methodologies to a problem relevant for the PhD research is welcome. Alternatively, the student is requested to deliver a short presentation/discussion on the content of an article based on methodologies related to those presented in the course.

Prerequisites:
Numerical Method for the Solution of Partial Differential Equations.

Schedule Information

Lecture	Day	Time
1	12/04/2021	9.00-11.00
2	13/04/2021	14.00-17.00
3	10/05/2021	14.00-17.00
4	12/05/2021	14.00-17.00
5	17/05/2021	14.00-17.00
6	19/05/2021	14.00-17.00
7	24/05/2021	14.00-17.00