SCHOOL FOR ADVANCED STUDIES LUCCA

A.Y. 2025-2026

PhD in Systems Science, Track in Computational Mechanics

MUSAM - Multi-scale Analysis of Materials Research Unit

Syllabi

Selected Courses open to external students

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Incoming Visiting Students

Single Courses for Visiting Students

The IMT School for Advanced Studies Lucca gives students the opportunity to take courses for free. Only students who are currently enrolled or already graduated in a university can apply to the Visiting students program. Applicants will be evaluated based on their overall profile (GPA, CV, etc.).

When to apply

Requests for enrollment can be submitted up to 15 days before the start of the course; acceptance of requests received thereafter cannot be guaranteed. In case the application is submitted shortly before the starting date of the course, send also an email to Prof. Marco Paggi (marco.paggi@imtlucca.it) with the requested application data (see below).

How to apply

See the instructions at: https://www.imtlucca.it/corsi-visiting-students

1. Check the course(s) in the list of syllabi. Their scheduling (in progress) can be seen on the online calendar:
    - Calendar PhD System Science (SYS 41)
2. Fill in the online form and click on "send" (please fill in one new form for each course).
3. You will be required to enter your personal data, contacts and information on your academic curriculum.

List of documents you need to provide:
- Your CV with passport-size picture

Enrollment

In order to complete the enrolment, you will receive an automatic email and will be required to fill out another online form.
In case of in-person participation, you will also be required to sign a document at the PhD and Higher Education Office (Piazza San Ponziano, 6 Lucca) before starting to attend the course(s) you have chosen.

Other information

To enquire about the availability of accommodation and/or to book the canteen at a special rate, please email facilities@imtlucca.it

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Fundamentals of Numerical Analysis

Lecturer(s): Andrea Mola

20 Hours

Learning Outcomes:

Develop awareness on the impossibility to find analytical and closed form solutions for the vast majority of mathematical problems commonly encountered in physics, engineering and economy, and the consequent need for numerical solutions. Ability to select the most convenient algorithm to obtain the numerical solution of the mathematical problems discussed. Implementing numerical algorithms in suitable computer programs, and learning how to use external libraries of numerical software.

Abstract:

The course introduces numerical algorithms that provide an approximation of the exact solution to several mathematical problems that are recurrent in physics, engineering and economy, such as of linear and nonlinear algebraic equations and systems, obtaining the numerical interpolation of a prescribed function, determining the numerical estimate of a function integral, as well as the matrices eigenvalues and eigenvectors. Along with providing motivation for the necessity of numerical solution schemes for each problem considered, the course also discusses the validity of each approach described both in terms of solution accuracy and computational cost, and describes the implementation of the numerical algorithms in suitable Python programs.

Lecture Contents:

- Motivation for numerical analysis and examples of relevant problems for which only numerical solution is accessible
- Fundamental definitions on general numerical algorithms and schemes
- Solution of linear algebraic systems by means of direct methods
- Solution of linear algebraic systems by means of iterative methods
- Solution of nonlinear algebraic equations and systems
- Numerical interpolation
- Numerical integration schemes
- Matrix Eigenvalue and Singular Value Decomposition algorithms

Teaching Method:

Blackboard, computer slides and Phyton programming sessions.

Bibliography:

- A. Quarteroni, R. Sacco, and F. Saleri. Numerical mathematics, volume 37 of Texts in Applied Mathematics. Springer-Verlag, New York, 2000. [E-Book-ITA] [E-Book-ENG]
- D. Arnold. A concise introduction to numerical analysis. Institute for Mathematics and its Applications, Minneapolis, 2001. [E-Book-ENG]

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 mostly self-contained. Fundamentals of algebra and calculus are required.

Numerical Methods for the Solution of Partial Differential Equations

Lecturer(s): Marco Paggi

20 hours

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 behavior 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 programs 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:

The lectures will be taught using blackboard and video-presentations.

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, although the course "Fundamentals of Numerical Analysis" is recommended.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Computational Fluid Dynamics for Incompressible Fluids

Lecturer(s): Andrea Mola

25 hours

Learning Outcomes:

The course is aimed at providing the students with an overview of the phenomenological behavior of incompressible fluids, as well as its mathematical description. A further objective of the course is that of stimulating the students to associate physical hypotheses and assumptions on the kind of flow and fluid, with the corresponding terms appearing in the equations governing the mathematical model. Finally, it will provide the students with examples of practical implementation of algorithms discretizing the partial differential equations governing the fluids' flow.

Abstract:

The course discusses the derivation of the balance equation for fluids, as well as the constitutive laws leading to the Navier—Stokes Equations. It then illustrates the potential flow obtained under the assumptions of incompressible fluid and irrotational flow. Details on the Laplace equation for the velocity potential, and boundary conditions will be provided, as well its discretization via Boundary Element Method (BEM) and examples of applications of flows past wings and ships.
Incompressible viscous fluid at low speed resulting in Stokes model will be discussed with examples such as micro swimmers. Incompressible viscous fluids at higher speeds will be then introduced, focusing on algorithms for pressure-velocity coupling, and turbulence modeling.
Discretization algorithms of the resulting Reynolds Averaged Navier--Stokes equations both via Finite Volume method and Smoothed Particle Hydrodynamics will be discussed. A brief description of Large Eddy Simulation approach will finally be provided.

Lecture Contents:

- Derivation and review of the fluid dynamic problems govern equations
- Incompressible fluid and irrotational flow: potential flow theory
- Potential flow for aerodynamics of wings and lifting surfaces
- Potential flow for free surface problems in ship hydrodynamics and ocean waves
- Zero Reynolds number limit and Stokes flow
- Boundary Element Method discretization for Laplace and Stokes equation
- Higher Reynolds viscous flows. Navier—Stokes Equations and Pressure-velocity coupling
- Turbulence and its modeling, from RANS to LES
- Discretization methods via Finite Volumes and Smoothed Particle Hydrodynamics

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Teaching Method:

Blackboard, computer slides and programming sessions.

Bibliography:

-D.C. Wilcox Turbulence modelling for CFD [E-Book-ITA] [E-Book-ENG]

- J. N. Newman Marine Hydrodynamics [E-Book-ENG]

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 mostly self-contained. Fundamentals of algebra and calculus are required.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Computational Contact and Fracture Mechanics

Lecturer(s): Marco Paggi, Pietro Lenarda

20 hours

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 subject to surface interactions, fracture and damage.

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;
- phase field modeling of fracture;
- applications to materials science, retrofitting of civil/architectonic structures, composite materials.

Teaching Method:
The lectures will be taught using standard presentations.

Bibliography:

Contact Mechanics

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

J Bonari, M Paggi, J Reinoso (2021) A framework for the analysis of fully coupled normal and tangential contact problems with complex interfaces, Finite Elements in Analysis and Design 196, 103605.

A Bemporad, M Paggi (2015) Optimization algorithms for the solution of the frictionless normal contact between rough surfaces, International Journal of Solids and Structures 69, 94-105.

M Ciavarella, JA Greenwood, M Paggi (2008) Inclusion of “interaction” in the Greenwood and Williamson contact theory, Wear 265 (5-6), 729-734.

M Paggi, M Ciavarella (2010) The coefficient of proportionality κ between real contact area and load, with new asperity models, Wear 268 (7-8), 1020-1029.

G Zavarise, M Borri-Brunetto, M Paggi (2007) On the resolution dependence of micromechanical contact models, Wear 262 (1-2), 42-54.

M Paggi, R Pohrt, VL Popov (2014) Partial-slip frictional response of rough surfaces, Scientific reports 4 (1), 1-6.

Fracture Mechanics

M Paggi, J Reinoso (2017) Revisiting the problem of a crack impinging on an interface: a modeling framework for the interaction between the phase field approach for brittle fracture and the interface cohesive zone model, Computer Methods in Applied Mechanics and Engineering 321, 145-172.

J Reinoso, M Paggi, C Linder (2017) Phase field modeling of brittle fracture for enhanced assumed strain shells at large deformations: formulation and finite element implementation, Computational Mechanics 59 (6), 981-1001.

M Paggi, P Wriggers (2016) Node-to-segment and node-to-surface interface finite elements for fracture mechanics, Computer Methods in Applied Mechanics and Engineering 300, 540-560.

J Reinoso, M Paggi (2014) A consistent interface element formulation for geometrical and material nonlinearities, Computational Mechanics 54 (6), 1569-1581.

M Paggi, P Wriggers (2012) Stiffness and strength of hierarchical polycrystalline materials with imperfect interfaces, Journal of the Mechanics and Physics of Solids 60 (4), 557-572.

M Paggi, JR Barber (2011) Contact conductance of rough surfaces composed of modified RMD patches, International Journal of Heat and Mass Transfer 54 (21-22), 4664-4672.

M Paggi, P Wriggers (2011) A nonlocal cohesive zone model for finite thickness interfaces–Part I: mathematical formulation and validation with molecular dynamics, Computational Materials Science 50 (5), 1625-1633.

M Paggi, P Wriggers (2011) A nonlocal cohesive zone model for finite thickness interfaces–Part II: FE implementation and application to polycrystalline materials, Computational Materials Science 50 (5), 1634-1643.

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.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Reduced Order Models and Coarse Graining Techniques

Lecturer(s): Tommaso Gili, Andrea Mola, Marco Paggi, Mirco Tribastone

30 hours

Learning Outcomes:

Knowledge of the different techniques that can be applied to large scale systems of equations to reduce their complexity, depending on the features of the underlying physical problem. A critical analysis of the analogies and differences of each method will be provided from a multi-disciplinary perspective. Concrete applications to mechanics, bio-informatics and economics will be discussed.

Abstract:

High-fidelity models in fluid and solid mechanics and in bio-informatics, describing the evolution of physical problems in space and/or in time, lead to large systems of algebraic equations. The course will introduce three different techniques developed in three different fields such as numerical analysis, computational mechanics and bio-informatics, to reduce the computational complexity of the high-fidelity models, leading to reduced models with the same solutions as the original ones. The course will also introduce the methods to rescale large-scale systems of interacting agents with and without a geometric embedding, thanks to the Renormalization Group Theory that allows the description of processes close to a critical point.

Lecture Contents:

- Introduction, motivations and an interdisciplinary perspective: importance for computational mechanics (CFD, solids), bio-informatics and economics (1h, Andrea Mola).
- Reduced Order Models based on Proper Orthogonal Decomposition (POD). Sampling. Greedy Algorithm and other techniques. POD with interpolation for the approximation of the output of parametric problems (3h, Andrea Mola).
- Dynamic Mode Decomposition for approximating time dependent problems. The combination of POD and DMD for the approximation of time dependent parameterized problems output (3h, Andrea Mola).
- Reduction of parameter space dimension: active subspace analysis (3h, Andrea Mola).
- Automatic generation of reduced models for sets of ordinary differential equations and applications to bio-informatics (5h, Mirco Tribastone).
- Homogenization techniques to reduce partial differential equations with spatially heterogeneous parameters (5h, Marco Paggi).

- Introduction to Legendre transformations, thermodynamic potentials and phase transitions. First-order and Second-order phase transitions. Order Parameters, Critical Exponentials, Universality Classes (2h, Tommaso Gili).
- 1D Ising Model and the Transfer Matrix Method. The Kadanoff Real Space Renormalization Scheme. Renormalization Group for the 1D Ising Model (2h, Tommaso Gili).
- The Migdal-Kadanov renormalization scheme for the 2D Iisng Model. Coase-graining in non-metric spaces. Box covering of a graph. The real-space RG of networks and self-similarity. Diffusion in discrete spaces. The combinatorial laplacian. The density operator and the connection with quantum statistical mechanics (2h, Tommaso Gili).
- The incidence matrix and its relationship with the combinatorial Laplacian. Entropic susceptibility in graphs and scale-invariance. The Laplacian Renormalization Group for heterogeneous networks and its applications (2h, Tommaso Gili).
- The incidence matrix and its relationship with Hypergraphs, the Cross-Order Laplacian and the Higher Order Renormalization Group. Group Symmetries and Fibration Symmetries. Cluster Synchronization, Equitable Partitions in a Graph and its relationship with cluster synchronization. Graph coloring and coarse-graining through symmetry (2h, Tommaso Gili).

Teaching Method:
The lectures will be taught using a standard presentation. Interactive hands-on examples will be discussed.

Bibliography:

T.I. Zohdi, P. Wriggers (2005) An Introduction to Computational Micromechanics, Lecture Notes in Applied and Computational Mechanics, Springer-Verlag Berlin Heidelberg, ISBN: 978-3-540-77482-2.

A. Bacigalupo, M. Paggi, F. Dal Corso, D. Bigoni (2018) Identification of higher-order continua equivalent to a Cauchy elastic composite, Mechanics Research Communications, 93:11-22, https://doi.org/10.1016/j.mechrescom.2017.07.002

Schilders, Wilhelmus HA, Henk A Van der Vorst, and Joost Rommes (2008). Model Order Reduction: Theory, Research Aspects and Applications. Vol. 13. Springer. https: //doi.org/10.1007/978-3-540-78841-6

Constantine (2015) Active subspaces: Emerging ideas for dimension reduction in parameter studies. Volume 2 SIAM Spotlights. https://doi.org/10.1137/1.9781611973860

Kutz, Brunton, Brunton, Proctor (2016) Dynamic Mode Decomposition: Data-Driven Modeling of Complex Systems. SIAM Other Titles in Applied Mathematics. https://doi.org/10.1137/1.9781611974508

Kerson Huang, Statistical Mechanics, Wiley 2008

Kim Christensen and Nicholas Moloney, Complexity and Criticality, Imperial College Press 2005

Piet Van Mieghem, Graph Spectra for Complex Networks, Cambridge University Press 2011

Battiston, Federico, and Giovanni Petri. Higher-order systems. Springer, 2022.

Villegas, Pablo, Tommaso Gili, Guido Caldarelli, and Andrea Gabrielli. "Laplacian renormalization group for heterogeneous networks." Nature Physics 19, no. 3 (2023): 445-450.

Morone, Flaviano, Ian Leifer, and Hernán A. Makse. "Fibration symmetries uncover the building blocks of biological networks." Proceedings of the National Academy of Sciences 117, no. 15 (2020): 8306-8314.

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.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Advanced Topics of Computational Mechanics

Lecturer(s): Pietro Lenarda
20 hours

Learning Outcomes:

Mathematical modelling and numerical methods for the simulation of coupled problems, with applications to renewable energy materials and biomechanics.

Abstract:

This course covers advanced topics of computational mechanics, with special emphasis on numerical methods to solve nonlinear coupled problems in solid mechanics (thermal, mechanical and electric fields, with applications to photovoltaics and thermo-piezo-electric materials) and in fluid dynamics (electro-physiology and mechanics of heart tissue, advection-reaction-diffusion systems).

Lecture Contents:

The course content covers the following topics:
- Advanced numerical techniques for coupled nonlinear solid mechanics and fluid dynamics problems.
- Coupled problems in materials for renewable energy applications.
- Coupled problems in biomechanics.

Teaching Method:
The lectures will be taught using standard presentations.

Bibliography:

M Paggi, S Kajari-Schröder, U Eitner (2011) Thermomechanical deformations in photovoltaic laminates, The Journal of Strain Analysis for Engineering Design 46 (8), 772-782.

M Paggi, M Corrado, MA Rodriguez (2013) A multi-physics and multi-scale numerical approach to microcracking and power-loss in photovoltaic modules, Composite Structures 95, 630-638.

A Sapora, M Paggi (2014) A coupled cohesive zone model for transient analysis of thermoelastic interface debonding, Computational Mechanics 53 (4), 845-857.

M Paggi, M Corrado, I Berardone (2016) A global/local approach for the prediction of the electric response of cracked solar cells in photovoltaic modules under the action of mechanical loads, Engineering Fracture Mechanics 168, 40-57.

F Fantoni, A Bacigalupo, M Paggi (2017) Multi-field asymptotic homogenization of thermo-piezoelectric materials with periodic microstructure, International Journal of Solids and Structures 120, 31-56.

M Gagliardi, P Lenarda, M Paggi (2017) A reaction-diffusion formulation to simulate EVA polymer degradation in environmental and accelerated ageing conditions, Solar Energy Materials and Solar Cells 164, 93-106.

U Jahn, M Herz, M Köntges, D Parlevliet, M Paggi, I Tsanakas (2018) Review on infrared and electroluminescence imaging for PV field applications: International Energy Agency Photovoltaic Power Systems Programme: IEA PVPS Task 13, Subtask 3.3, International Energy Agency.

P Lenarda, M Paggi, RR Baier (2017) Partitioned coupling of advection–diffusion–reaction systems and Brinkman flows, Journal of Computational Physics 344, 281-302.

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.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Principles of Digital Twins

Lecturer(s): Maria Rosaria Marulli, Andrea Mola, Marco Paggi

20 hours

Learning Outcomes:

Ability to create digital twin models of products and processes, integrating computer aided design and real geometrical data with computer aided engineering tools. Both high-fidelity (model-based) simulations and data-driven (artificial neural networks) models are presented and discussed with practical examples.

Abstract:

Digital twins represent the digital counterparts of real processes or products and are one of the enabling technologies for Industry 4.0. Equipped with simulation tools, they can effectively reduce the time requested for product innovation and the associated R&D costs. Moreover, coupled with optimization and control, they can be exploited to test scenarios that cannot be easily assessed experimentally in order to identify innovative optimal solutions. The course covers, in a self-contained manner, the fundamentals of simulation tools to create digital twins for both high-fidelity (model-based) simulations and data-driven (artificial neural networks) models.

Lecture Contents:

- Introduction to digital twins and their use in technology (1h, Marco Paggi).
- Data-driven models based on artificial neural networks: neurons, activation functions, cost functions, back-propagation algorithm for a simple artificial neural network (1h, Marco Paggi).
- Artificial neural networks for linear and nonlinear classification problems (1h, Marco Paggi).
- Time series networks (1h, Marco Paggi)
- Convolutional neural networks (1h, Marco Paggi)
- From Computer Aided Design (CAD) or real geometrical data (from images, laser scanner, etc.) to Computer Aided Engineering (CAE): how to integrate realistic object geometries in simulation tools (3h, Maria Rosaria Marulli).
- Digital twins for cultural heritage (2h, Maria Rosaria Marulli).
- User element routines for model-based simulations of surface problems (5h, Maria Rosaria Marulli).
- Interfaces between different CAE software (1h, Andrea Mola).
- Integrating functions from software libraries in CAE simulation tools (2h, Andrea Mola).
- Integrating data driven information in numerical models (2h, Andrea Mola)

Teaching Method:

The lectures will feature both lessons delivered using standard presentations, and hands-on interactive examples.

Bibliography:
Specific didactic material tailored to the course contents will be provided to the students before the scheduled lessons.

Final Exam:
The final exam will be based on the evaluation of an application of the taught methodologies to one case study of relevance for the PhD student's research.

Prerequisites:
The course is self-contained. Fundamentals of algebra are required. A general knowledge on CAD and CAE software is recommended.

IMT SCHOOL FOR ADVANCED STUDIES LUCCA

Digital Twins for Health

Lecturer(s): Pietro Lenarda

20 hours

Learning Outcomes:

Mathematical modeling and numerical methods for the simulation of coupled problems, with applications to biomechanics.

Abstract:

This course covers state-of-the-art numerical methods to solve problems arising in bio-medical engineering and advanced modeling of the mechanics and electro-physiology of human tissues.

Lecture Contents:

The course content covers the following topics:

1. Phase field modeling and simulation of damage occurring in human vertebra after screws fixation procedure. Fractures inside the human vertebra can be challenging to analyze and treat due to their complex shapes and locations. The phase field modeling can help simulate the fracture process and shedding light on the underlying mechanisms involved.

2. Exploring novel 3-D in vivo bioprinting technology inside the gastrointestinal system: perspectives and new frontiers. For most of the digestive system diseases, endoscopy is the most basic clinical and effective method. Now scientists aim to treat such problems by exploring a new frontier in 3-D printing: depositing living cells directly inside the human body.

The development of a computational model for gastrointestinal mechanics leads to patient-specific in-silico tools unveiling the principles governing food digestion and disease mechanisms at different scales. The course will provide a numerical framework for the treatment of the gastro-intestinal system. In particular the Holzapfel-Ogden model coupled with electrophysiology will be discussed and analyzed.

3. Nanoparticle technology for cancer therapy is a growing area of cancer nanomedicine because of the potential for localized and targeted destruction of cancer cells. Localized effects are dependent on many factors, including nanoparticle size, shape, stiffness and surface properties. Computational modeling is an important tool for investigating and optimizing these parameters. The present course will provide coupled Lattice-Boltzmann Immersed boundary methods for the simulation of transport of deformable cells and nano-particles in three dimensional microcapillary flows and how to model the receptor-ligand mediated adhesion dynamics of deformable nanoparticles in whole blood capillary flow.

Teaching Method:

The lectures will be taught using standard presentations.

Bibliography:

R. Cavuoto, P. Lenarda, D. Misseroni, M. Paggi, D. Bigoni (2022) Failure through crack propagation in components with holes and notches: An experimental assessment of the phase field model International Journal of Solids and Structures

P. Lenarda, A. Coclite, P. Decuzzi (2019) Unraveling the vascular fate of deformable circulating tumor cells via a hierarchical computational model Cellular and Molecular Bioengineering

A. L. Palange, M. Ferreira, D. Di Mascolo, R. Palomba, P. Lenarda, A. Cook, P. Decuzzi (2020) Rational Design of Polymeric Nanoconstructs for Drug Delivery and Biomedical Imaging, Handbook of Harnessing Biomaterials in Nanomedicine, Jenny Stanford Publishing

P. Lenarda, A. Gizzi, M. Paggi (2018) A modeling framework for electro-mechanical interaction between excitable deformable cells European Journal of Mechanics - A/Solids

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.

Enabling Digital Technologies: Technical Aspects and Impact

Lecturer(s): Marco Paggi

10 hours

Learning Outcomes:

The student will learn which are the major digital technologies and how they can effectively impact on industrial productivity, both individually and holistically.

Abstract:

The course will provide an introduction and an overview to the major enabling digital technologies that will be specifically addressed in detail in other courses of the PhD program and that are expected to have a disruptive impact on industrial productivity and agility in the so-called Industry 4.0 revolution.

Lecture Contents:

The course will cover an overview to the following enabling digital technologies:
- digital twins and virtual testing
- big data analytics
- artificial intelligence and automation for quality control
- additive manufacturing
- augmented reality
- cybersecurity
- high performance computing

Practical applications are presented for each digital technology with also a holistic perspective, along with its impact on a lean factory based on key performance indicators of industrial relevance.

Teaching Method:

The lectures will be taught using standard presentations.

Bibliography:

Specific didactic material tailored to the course contents will be provided to the students before the scheduled lessons.

Final Exam:
No final exam.

Prerequisites:
The course is self-contained.

Funding Opportunities and Management of Intellectual Property

Lecturer(s): Marco Paggi
10 hours

Learning Outcomes:

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

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.)

Teaching Method:
The lectures will be taught using standard presentations.

Bibliography:
Handouts are provided to the participants.

Final Exam:
No final exam.

Prerequisites:
The course is self-contained.

Fundamentals of Academic Entrepreneurship

Lecturer(s): Marco Paggi, Francesco Biancalani

10 hours

Learning Outcomes:

The student will learn the fundamentals of academic entrepreneurship from a theoretical perspective, along with an overview of practical case studies of successful academic startup projects.

Abstract:

According to the European Commission Research and Innovation Strategy 2020-2024, "new knowledge and breakthrough innovation will drive the green and digital transformations that are underway in our society. They will help us move faster towards a sustainable and prosperous future for people and the planet, based on solidarity and respect for shared European values". Actually, although research and innovation are often mentioned together, they have profound differences and only sometimes one implies the other as a direct consequence. Very often, research and innovation do not have the same purpose or simply do not share the same timing, which implies that only a small portion of all the research discoveries lead to innovations transferable to the world of business. In this long seminar, methods to foster innovation from research are presented and discussed in relation to practical case studies of successful innovative startups.

Lecture Contents:

The course will cover the following fundamentals of academic entrepreneurship:
- the players of research and innovation and their roles (1h, Marco Paggi)
- methods to foster innovation (R&D contracts, public-private joint labs, patents, university spin-offs, public-private joint Ph.D. programs) (1h, Marco Paggi)
- university spin-offs (1h, Marco Paggi)
- elevator pitches (2h, Marco Paggi)
- triple helix model of innovation (1h, Francesco Biancalani)
- business plans (1h, Francesco Biancalani)
- testimonials presenting case studies of academic entrepreneurship (3h, Francesco Biancalani)

Teaching Method:

The lectures will be taught using standard presentations.

Bibliography:

Handouts are provided to the participants.

Final Exam:
No final exam.

Prerequisites:
The course is self-contained, although fundamentals of intellectual property rights are provided in the long seminar "Funding Opportunities and Management of Intellectual Property".